Bacteria TMDL for (non-tidal) Mill Creek including Un-named Tributary to Kissinger Millpond, and Kissinger Millpond

Tributaries of the South Yeocomico River in Northumberland County, Virginia

Submitted by

Virginia Department of Environmental Quality

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Executive Summary

This report presents the development of a Bacteria Total Maximum Daily Load (TMDL) for the Mill Creek watershed. The Mill Creek watershed is located in Northumberland County in the Potomac River Basin (USGS Hydrologic Unit Code 02070011). The waterbody identification code (WBID, Virginia Hydrologic Unit) for Mill Creek is VAP-A33R-01-BAC and is located in the Coastal Plain region of Virginia.

The bacteria impairment for Mill Creek is 3.94 miles long beginning in the headwaters near Village, Virginia and extending downstream to the upper extent of the tidal limits just below the Courtney Millpond dam (also known as Kissinger Millpond).

The drainage area of the Mill Creek watershed is 5.2 square miles. The average annual rainfall as recorded at Warsaw, VA is 42.31 inches. The watershed study area is approximately 3327 acres, which is predominately forested (48.4 percent). Agriculture encompasses 45.1 percent of the watershed, with 18.4 percent cropland and 26.7 pasture/hayland. Residential areas compose approximately 4 percent of the land base. The remaining 2.4 percent of the watershed is comprised of wetlands (1.9%), open water (0.4%), and barren (0.1%, cleared land or parking lots). The distribution of land use in the watershed indicates that the wetlands and forest tend to be located closer to streams, while the crop and pasture land is farther and upland from the stream. Visual confirmation revealed that most pasture landuse along Routes 360, 617 and 619 surrounding the watershed are currently cropland. Only two pastures existed along those routes, totaling approximately14.6 acres containing 50 cattle.

Mill Creek was listed as impaired on Virginia's 2002 303(d) Report on Impaired Waters (VADEQ 2003) due to violations of the State's water quality standards for fecal coliform bacteria at Route 202 (station 1AMIA004.12). Of the 28 fecal coliform bacteria samples collected at station 1AMIA004.12 from May 1996 to April 2001, 4 violated the water quality standards (14% violation rate). The extent of the 2002 impairment spanned from the headwaters downstream past Rt. 202 to the upstream end of Kissinger Millpond for a total of 3.94 impaired non-tidal stream miles. In 2003, VA DEQ switched from fecal coliform to *E. coli* as the indicator organism in non-tidal waters for the primary recreational use water quality standard. Monitoring conducted in preparation for this TMDL study (July 2008 to June 2009) indicated the bacteria impairment of Mill Creek was still present based on 3 *E. coli* violations out of 12 samples at station 1AMIA004.12 (25% violation rate).

Although the originally impaired downstream boundary lies above Kissinger Millpond, DEQ has included Kissinger Millpond and its unnamed tributary (UT) in the watershed for the purposes of this study. The collective watershed includes Mill Creek from its headwaters to the tidal limit just below Kissinger Millpond (also known as Courtney Millpond) dam, Kissinger Millpond, and UT to Kissinger Millpond. DEQ also monitored E. coli at the Rt. 620 bridge at the dam of Kissinger Millpond from July 2008 to May 2009. Of the 11 E. coli bacteria samples collected at station 1AMIA002.34, 3 violated the water quality standards (27% violation rate).

According to Virginia Water Quality Standards (9 VAC 25-260-10A), "all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

As indicated above, Mill Creek and tributaries must support all designated uses and meet all applicable criteria. Mill Creek does not currently support primary contact recreation.

Assessment of bacterial sources involves estimating loads from various sources in the watershed. A search of the watershed revealed there were no point-source bacterial load contributors in the watershed, therefore, all bacteria loads in the study watershed were determined to be non-point sources. There is a single facility which holds a General Permit for Industrial Stormwater, however stormwater permits do not typically have bacterial permit limits, hence there are no permitted *E. coli* loads for these facilities. However, a one percent wasteload allocation (WLA) was included for future growth in the watershed.

For non-point sources (human, pets, livestock, and wildlife), total daily and annual fecal production rates were calculated and an inventory of all known source types within the watershed was assembled. The sources and their respective rates were used to derive relative percent fecal coliform production rates. These relative percents were then applied to the loads calculated as a result of the load-duration method. This resulted in load allocations for each non-point source type.

The load-duration method essentially uses an entire stream flow record to provide insight into the flow conditions under which exceedances of the water quality standard occur. There was no gaging station in the Mill Creek watershed. Therefore, the flow-duration curves were developed using historical flow data collected at the USGS gaging station Piscataway Creek near Tappahannock, VA (#01669000). The load-duration curve for Mill Creek was then developed by multiplying the flow level along the flow-duration curve by the applicable water quality standard and required unit conversions. Each water quality observation was then assigned to a flow interval by comparing the date of each water quality observation to the flow record of the reference stream. The stream flow from the date of the water quality observation was then used to calculate a stream flow and flow-duration interval for the stream. The load-duration curve produced daily loads. Fecal coliform data was converted to E. coli using a translator equation developed based on the data sets from the DEQ's statewide monitoring network. The observed loads were plotted on the load-duration curve to determine the number and pattern of exceedances of water quality standards.

In previous TMDLs using this methodology, the curve was transformed from daily loads to annual loads by multiplying each point along the curve by 365. Though not required by EPA, the annual loads are included in this report because of their usefulness during implementation planning and implantation.

The results indicated that the highest exceedance of the water quality standard on Mill Creek occurred at low flows that were exceeded approximately 97% of the time, at 1.35 cubic feet per second (cfs). This represents the flow condition under which the largest bacteria reduction is required in order to meet water quality standards. The translated load at this low flow condition was 2.39E+11 cfu/day. Under the instantaneous *E. coli* standard of 235 cfu/100mL, this load would have to be reduced by 97% to an allowable load of 7.79E+09 cfu/day at low flow. The allowable load is simply the *E. coli* standard multiplied by the applicable flow condition and the proper unit conversions.

For Mill Creek the one percent flow duration daily *E. coli* load is 1.22E+12 cfu/day, and the daily TMDL load under one percent flow duration is 3.98E+10 cfu/day. These values are used to calculate required reductions. Although there are no point sources with bacterial permit limits in either watershed, it is reasonable to assume future growth will occur. For this reason, a wasteload allocation (WLA) is set for one (1) percent of the total load allocation. This totals 3.98E+08 cfu/day for Mill Creek. The remaining load allocations (LA) address allowable non-point source bacterial contributions.

The TMDL, WLA and LA are presented as daily loads in Table E1 for Mill Creek. Table E2 shows the required daily LA reductions for Mill Creek. Full calculations are presented in Appendix C.

Table E1. Daily *E. coli* loads and TMDL for Mill Creek watershed (cfu/day).

WLA[2]	LA	MOS	TMDL[1]
3.98E+10	**3.94E+10**	Implicit	**3.98E+10**

1 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.
2 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Table E2. Daily TMDL and required reduction for Mill Creek.

Allowable Loads (cfu/day)		Current Daily EC Load (cfu/day)	Required Reduction
TMDL (daily)[1]	**3.98E+10**		
Wasteload Allocation (WLA)[2] 1%	**3.98E+08**		
MOS	Implicit		
Load Allocation (LA)	**3.94E+10**	**1.22E+12**	**97%**

1 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

2 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

The TMDL, WLA and LA are presented as annual loads in Table E3 for Mill Creek. Table E4 shows the annual required LA reductions for Mill Creek.

Table E3. Average Annual *E. coli* loads and TMDL for Mill Creek watershed (cfu/year)

WLA[2]	LA	MOS	TMDL[1]
5.91E+10	**5.85E+12**	Implicit	**5.91E+12**

1 – The annual TMDL is presented for the average annual flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.
2 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Table E4. Annual TMDL and required reduction for Mill Creek

Allowable Loads (cfu/year)		Current *E. coli* Load (cfu/year)	Required % Reduction
TMDL (annual)[1]	**5.91E+12**		
Wasteload Allocation (WLA)[2]	**5.91E+10**		
MOS	Implicit		
Load Allocation (LA)	**5.85E+12**	**1.82E+14**	**97%**

1 – The annual TMDL is presented for the annual average flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.
2 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

In order to attribute the loads by source type into a load allocation (LA) for the TMDL, the calculated fecal coliform productions (colony forming units (cfu)/animal/day) had to be related to the calculated load duration values for the current and total TMDL loads. This was done by summing the 4 non-point source type categories for fecal coliform production and then calculating the percent contribution of each source type to the total. The percent equivalent of the non-point source type fecal coliform production values are shown in Table E5

Table E5. Mill Creek watershed non-point source daily fecal coliform contribution

Non-Point Source Fecal Coliform Production Totals (cfu/day)		Percent Equivalent
Livestock	1.79E+12	90.82%
Domestic Pet	2.07E+10	1.05%
Wildlife	1.08E+11	5.46%
Human	5.27E+10	2.67%
Total	1.97E+12	100.00%

The Mill Creek watershed TMDL development presented in this report is the first step toward the attainment of water quality standards. The second step is to develop a TMDL implementation plan, and the final step is the field implementation of the TMDL to attain water quality standards.

The Commonwealth intends for this TMDL to be implemented through a process of phased implementation of best management practices (BMPs). The development of the Mill Creek TMDL requires a 97% reduction in non-point source loading for the Mill Creek watershed in order to attain a zero percent violation rate of the water quality standard. In order to evaluate interim reduction goals for a phased implementation plan, several reduction levels (75%, 65%, and 45%) and their associated violation rates were assessed. Reduction curves similar to the maximum exceedance/reduction curve were plotted and are presented in this report.

Based on the reduction analysis presented above and a goal of approximately 10.3% or fewer violations of the water quality standard, a suitable Phase I reduction level for Mill Creek would be 45%. Table E6 presents the Phase I load allocations for Mill Creek based on a 45% reduction of in-stream loads.

Table E6. Phase I Scenario with 45% Reduction (resulting in violation rate of 10.3%). Reductions were confined to Livestock non-point sources.

Impaired Waterbody	Fecal SourceType	Allocation % of Total Load	Current Load *E. coli* (cfu / day)	45% Reduction Scenario	45% ReductionTarget Load (cfu/day)
Mill Creek VAP-A33R-01-BAC	Wildlife	5.46%	6.66E+10	0%	0.00E+00
	Human	2.67%	3.26E+10	0%	0.00E+00
	Livestock	90.82%	1.11E+12	40%	6.71E+11
	Pets	1.05%	1.28E+10	0%	0.00E+00
	Total	100.00%	1.22E+12	45%	6.71E+11

At the 45 percent daily load reduction level, which results in a 10.3% violation rate (which is modeled to have the same benefit as 65% and 75% load reductions), the total allowable daily load (6.71E+11 cfu/day) is greater than the current wildlife load (6.66E+10 cfu/day). Much less severe reductions in livestock *E. coli* loads may be adequate to reduce *E. coli* loads and percent violations to less than 10 percent above the water quality standard. The use of staged implementation may indicate that the TMDL reduction may be achieved before the implementation of all possible BMPs.

During the first implementation phase, all controllable anthropogenic sources will be reduced to the maximum extent practicable using a staged approach. Following completion of the first phase, VADEQ would perform follow-up monitoring to re-assess water quality in the stream to determine if the water quality standard has been attained. If water quality standards are not being met, a Use Attainability

Analysis (UAA) may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources (wildlife).

In order to provide some insight into the nature of the Mill Creek water quality violations and to better target possible BMPs, the correlation between violations, stream flow change, and local precipitation was examined. Results indicate that approximately 86% of the violations occurred during times of precipitation and increasing stream flow or just after a precipitation event with stable or decreasing stream flow. This suggests that those violations could be related to runoff events.

BMPs effective in correcting dry weather/low-flow violations of the bacteria water quality standard typically include: streamside fencing for cattle exclusion, straight pipe replacement, and septic system repair. Among some of the BMPs effective in reducing bacteria runoff from precipitation events include: riparian buffers zone, retention ponds/basins, range and pasture management, and animal waste management. Detailed lists of BMPs and their relative effectiveness will be presented in the eventual TMDL implementation plan for the Mill Creek watershed.

The development of the Mill Creek TMDLs was not possible without public participation. The first set of public meetings were held at the Northumberland County Public Library in Northumberland, VA on December 16, 2009 to discuss the process for TMDL development and the source assessment input, which a total of 11 persons attended. The final set of public meetings to discuss the TMDL results and the draft report, including load allocations, were held at the Northumberland County Public Library on April 28, 2010, at which 2 persons attended. Copies of presentation materials were made available for public distribution. The public meetings were public noticed in the Virginia Register, the Northumberland Echo, and watershed signs were placed at prominent intersections approximately 2 weeks prior to each of the meetings. Thirty day-public comment periods were held after each public meeting in which XX comments were received.

1. Introduction

Section 303(d) of the Clean Water Act and US Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies which are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 1991).

The Commonwealth of Virginia's (Virginia's) 1997 Water Quality Monitoring, Information, and Restoration Act (WQMIRA) codifies the requirement for the development of TMDLs for impaired waters. Specifically section § 62.1-44.19:7 C states:

"The plan required by subsection A shall, upon identification by the Board of impaired waters, establish a priority ranking for such waters, taking into account the severity of the pollution and the uses to be made of such waters. The Board shall develop and implement pursuant to a schedule total maximum daily loads of pollutants that may enter the water for each impaired water body as required by the Clean Water Act. "

The EPA specifies that in order for a TMDL to be considered complete and approvable, it must include the following eight elements:

1. It must be designed to meet applicable water quality standards,
2. It must include a total allowable load as well as individual waste load allocations and load allocations,
3. It must consider the impacts of background pollution,
4. It must consider critical environmental conditions or those conditions (stream flow, precipitation, temperature, etc.) which together can contribute to a worst-case exceedance of the water quality standard,
5. It must consider seasonal variations which together with the environmental variations can lead to a worst-case exceedance,
6. It must include an implicit or explicit margin of safety to account for uncertainties inherent in the TMDL development process,
7. It must allow adequate opportunity for public participation in the TMDL development process,
8. It must provide reasonable assurance that the TMDL can be met.

The following document details the development of a bacteria TMDL for Mill Creek which was listed as impaired on Virginia's 2002 305(b) Water Quality Assessment Report. This report evaluates the bacteria impairment by using the Load Duration Approach (LDA) for the TMDL development study in the Mill Creek watershed. A LDA approach allows for characterizing water quality data at different flow regimes. The method provides a visual display of the relationship between stream flow and loading capacity. Using the duration curve framework, the frequency and magnitude of water quality standard exceedances, allowable and current loadings, and size of load reductions are easily presented and can be better understood (USEPA, 2006).

A glossary of terms used throughout this report is presented in Appendix A.

2. Physical Setting

2.1. Listed Water Bodies

Mill Creek (Figure 1) is a tributary of the South Yeocomico River located in Northumberland County in the Potomac River Basin (USGS Hydrologic Unit Code 02070011). The waterbody identification code (WBID, Virginia Hydrologic Unit) for Mill Creek is VAP-A33R-01-BAC and includes Assessment Unit (AU) VAP-

A33R_MIA01A00. Mill Creek was listed as impaired on Virginia's 2002 303(d) Report on Impaired Waters (VADEQ 2003) due to violations of the State's water quality standards for fecal coliform bacteria. In 2003 the VADEQ water quality standard indicator organism for non-tidal primary contact use changed to *E. coli*. This report evaluates the bacteria impairments by using the Load Duration Approach (LDA) for the TMDL development study in the Mill Creek watershed. An explanation of this method can be found in Section 6.1. Mill Creek flows into a pond just below Rt. 202. Locally, this pond is referred to as Kissinger Millpond (topographic maps show the pond to be named 'Courtney Millpond'), therefore for the duration of this study, the pond will be referred to as 'Kissinger Millpond'. A map detailing the impairment is in Figure 1, below. Although the original impairment downstream boundary is above Kissinger Millpond, DEQ has included Kissinger Millpond and its unnamed tributary (UT) in the watershed for the purposes of this study. The non-tidal fecal coliform impairment for Mill Creek is described in Table 1.

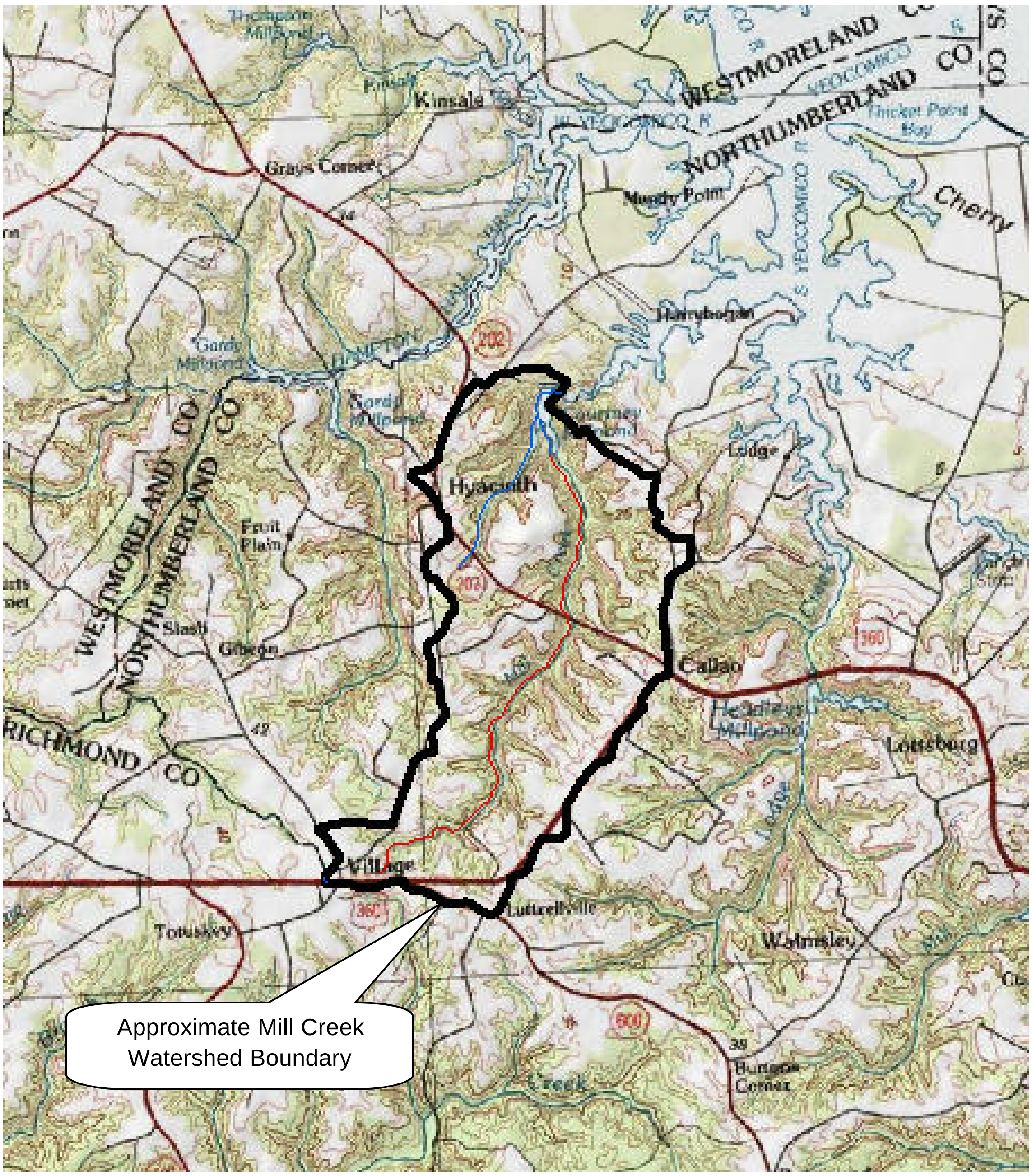

Figure 1. Topographic map of the non-tidal Mill Creek watershed. The red portion of the stream shows the 2002 impairment segment of Mill Creek.

Table 1. Impaired segment description from the 2002 VA DEQ 303d Report (Mill Creek)

Impaired Segment	Impairment	Upstream Limit Description	Downstream Limit Description	Miles Affected
Mill Creek (VAP-A33R-01-BAC)	Fecal Coliform (unknown source)	Headwaters	Rt. 202 above Courtney Millpond*	3.94

**Topographic maps show the pond above the tidal limit as "Courtney Millpond", however, locally the pond is call Kissinger Millpond*

2.2. Watershed Characterization

2.2.1. General Description

Mill Creek, located within Northumberland County, Virginia, is a minor tributary to the South Yeocomico River (Figures 1 & 2). Mill Creek is approximately 6.8 miles long and flows northeast from its headwaters near Village, VA, to its confluence with the South Yeocomico River. The study watershed has an area of approximately 5.2 m^2. Northumberland County has a land area of approximately 192.3 square miles (http://www.co.northumberland.va.us/index.htm). There is no continuous flow gaging station on Mill Creek, however, there is a gage on Piscataway Creek near Tappahannock, VA, (01669000) which is located approximately 16 miles southwest of Mill Creek, with a drainage area of approximately 28.0 mi^2.

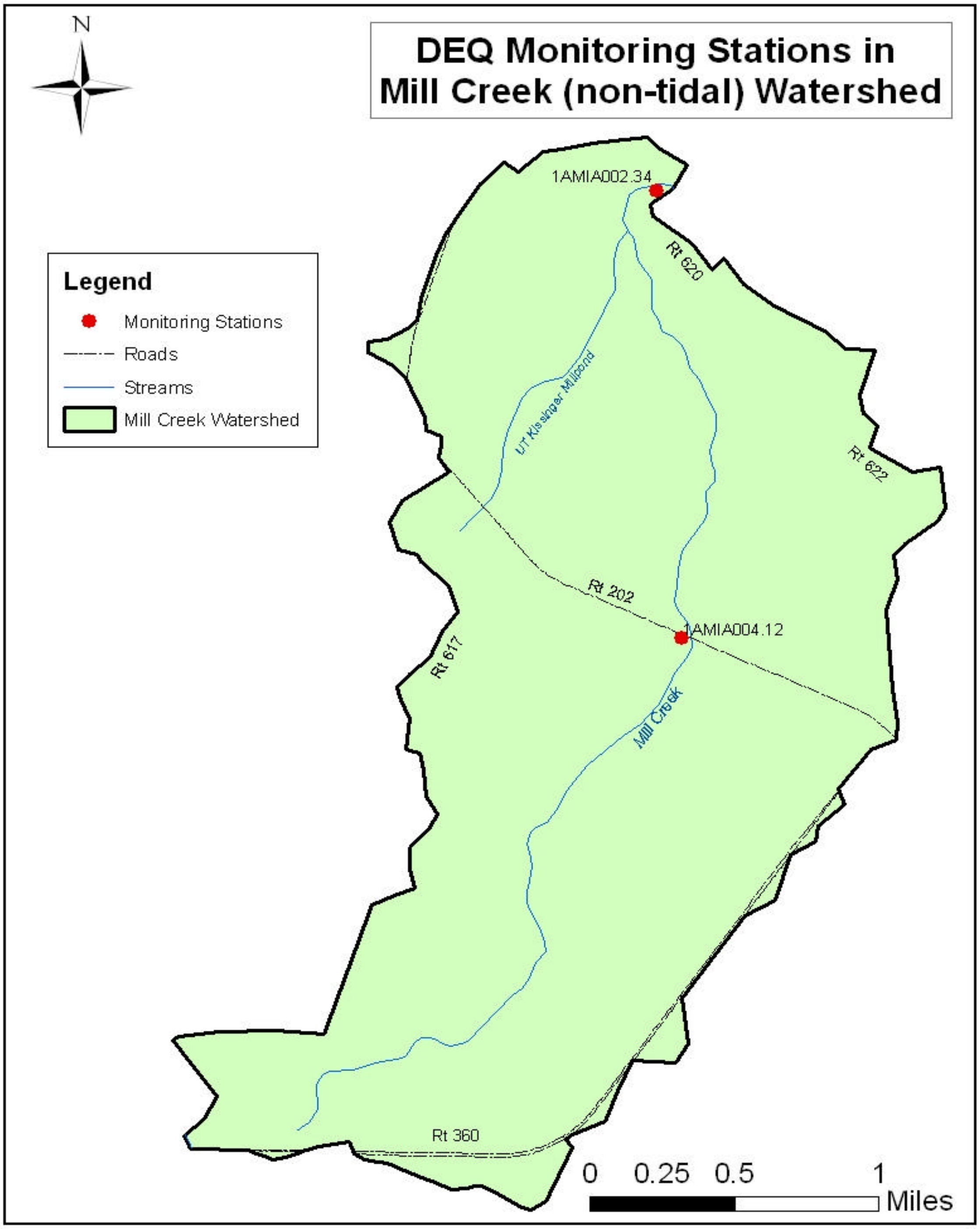

Figure 2. Mill Creek (non-tidal) monitoring stations

2.2.2. Geology, Climate, Land Use

Geology and Soils

Mill Creek is in the Atlantic Coastal Plain physiographic region. The Atlantic Coastal Plain is the easternmost of Virginia's physiographic provinces. The Atlantic Coastal Plain extends from New Jersey to Florida, and includes all of Virginia east of the Fall Line. The Fall Line is the easternmost extent of rocky river rapids, the point at which east-flowing rivers cross from the hard, igneous and metamorphic rocks of the Piedmont to the relatively soft, unconsolidated strata of the Coastal Plain. The Coastal Plain is underlain by layers of Cretaceous and younger clay, sand, and gravel that dip gently eastward. These layers were deposited by rivers carrying sediment from the eroding Appalachian Mountains to the west. As the sea level rose and fell, fossiliferous marine deposits were interlayered with fluvial, estuarine, and beach strata. The youngest deposits of the Coastal Plain are sand, silt and mud presently being deposited in our bays and along our beaches (DMME, 2008).

Soils for the Mill Creek watershed were documented utilizing the VA State Soil Geographic Database (STATSGO, 2006). Two general soil types were identified using in this database. Descriptions of these soil series were derived from queries to the USDA Natural Resources Conservation Service (NRCS) Official Soil Series Description web site (http://ortho.ftw.nrcs.usda.gov/cgi-bin/osd/osdname.cgi). Figure 3 shows the location of these general soil types in the watershed.

Soils of the Emporia-Johnston-Kenansville-Remlik-Rumford-Slagle-Suffolk-Tomotley (VA027) series are very deep to deep, and vary between well drained to poorly drained with moderately slow or slow permeability. They formed in moderately fine-textured stratified fluvial and marine sediments on the upper Coastal Plain and stream terraces.

Soils of the Tetotum-Nansemond-State-Emporia-Dragston-Nimmo-Bladen Series (VA036) are very deep and range from well drained to poorly drained. Permeability ranges from moderately rapid and/or rapid to moderately slow or slow. This soil series was formed in sandy or loamy fluvial and marine sediments on Coastal Plain uplands and stream terraces.

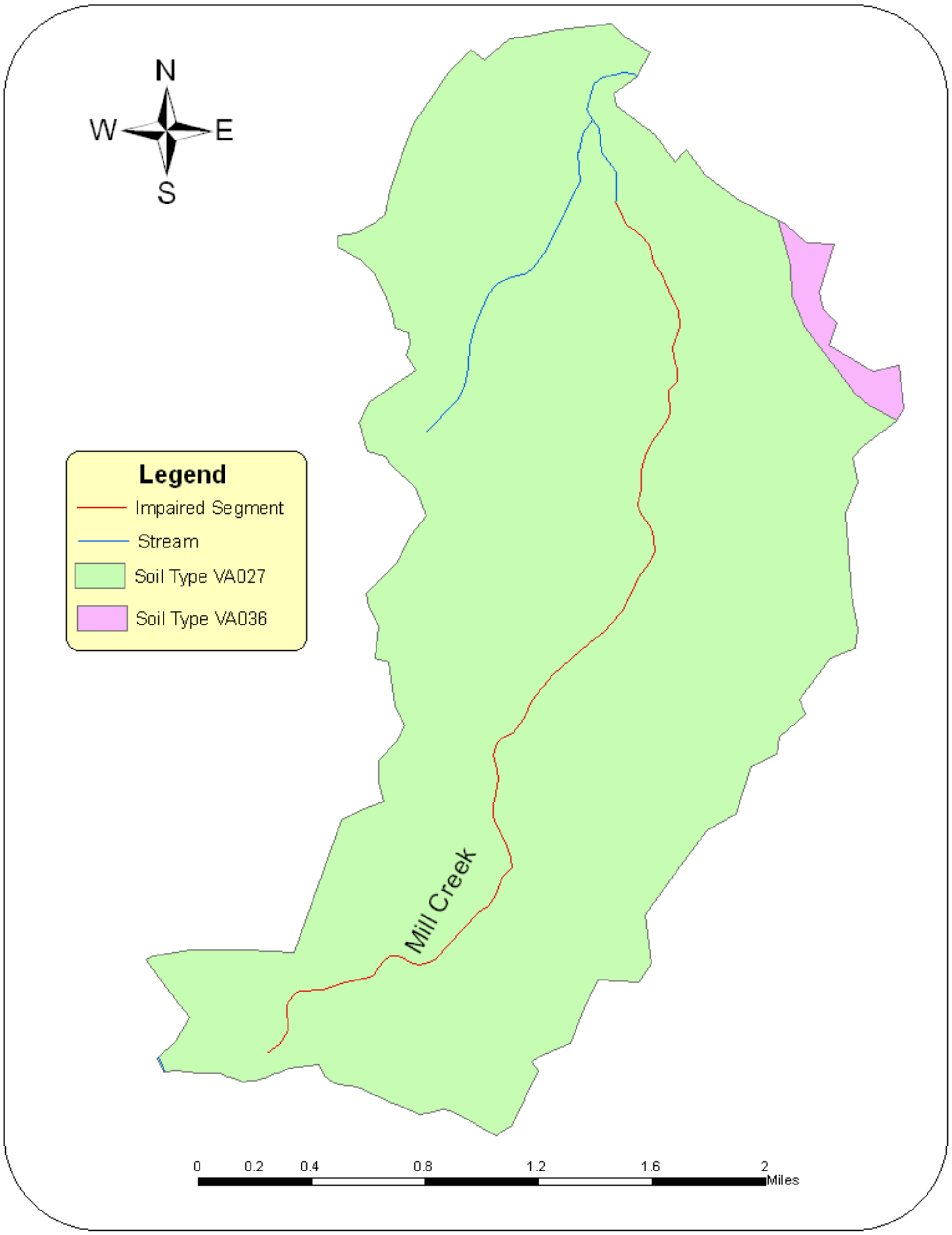

Figure 3. Soil Characteristics of the Mill Creek watershed

Climate

The climate summary for Mill Creek is derived from a weather station located in Warsaw, VA, with a period of record from 1/ 1/1893 to 8/31/2009. The average annual maximum and minimum temperature (°F) at the weather station is 68.3 and 46.6, respectively and the annual rainfall is 42.31 inches (Table 2). (Southeast Regional Climate Center, http://www.sercc.com/climateinfo/historical/historical_va.html).

Table 2. Climate summary for Warsaw 2 N, Virginia (448894) as of March 2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	46.6	49.1	58.3	68.6	77.3	84.6	87.9	86.5	80.6	70.6	59.8	49.3	68.3
Average Min. Temperature (F)	27.4	28.3	35.5	44.2	53.7	62.5	66.6	65.7	59.0	47.7	38.**3**	30.0	46.6
Average Total Precipitation (in.)	3.13	2.82	3.73	3.12	**3**.80	3.82	4.48	4.47	3.72	3.20	2.93	3.11	42.31

Land Use

The watershed is approximately 5.20 m^2 in size and is predominately forested (48.4 percent). Agriculture lands total approximately 45 percent of the watershed, with 26.7 percent pasture and 18.4 percent cropland. Urban land use, also referred to as "residential" and "high use industrial" areas, comprise 4 percent while the remaining 2.5 percent of the watershed is comprised of approximately 1.9 percent wetland, 0.4 percent open water, and 0.1 percent barren or mining land uses. Land use for the Mill Creek watershed is detailed in Table 3. Analysis of land uses within an impaired watershed is essential in the determination and verification of non-point source load allocations (LAs).

A map of the distribution of land use in the watershed (Figure 4) indicates the majority of the watershed is comprised of agriculture and forest land uses. Pockets of residential land use are evident along Routes 360 and 202.

Land use characterization was based on National Land Cover Data (NLCD, 2001), developed cooperatively by the U.S. Environmental Protection Agency and the U.S. Geological Survey. NLCD data is derived from satellite and aerial images circa 1992 (updated 2001). The NLCD is not able to precisely differentiate between cropland and pasture. Visual confirmation by DEQ staff revealed that most NLCD pasture landuse along Routes 360, 617 and 619 surrounding the watershed are currently cropland. Only two pastures existed along those routes, totaling 14.6 acres containing 50 cattle. Using this information, the Mill Creek watershed was estimated to contain approximately 44.7% cropland and 0.4% pasture. The total agricultural land was estimated to be unchanged. For more information of this data source and land use categorizations, please visit http://www.mrlc.gov/nlcd.

Table 3. Mill Creek watershed land use distribution by major land use category

Land Use Type[1]	Acres	Square Miles	Percent
Open Water	12	0.02	0.4%
Urban	135	0.21	4.0%
Barren or Mining	4	0.01	0.1%
Forest	1610	2.52	48.4%
Agri - Pasture	889	1.39	26.7%
Agri - Cropland	613	0.96	18.4%
Wetland	65	0.10	1.9%
Totals:	**3327**	**5.20**	**100%**

[1] [1]NLCD, 2001

Percents not adding up to 100% are a result of rounding

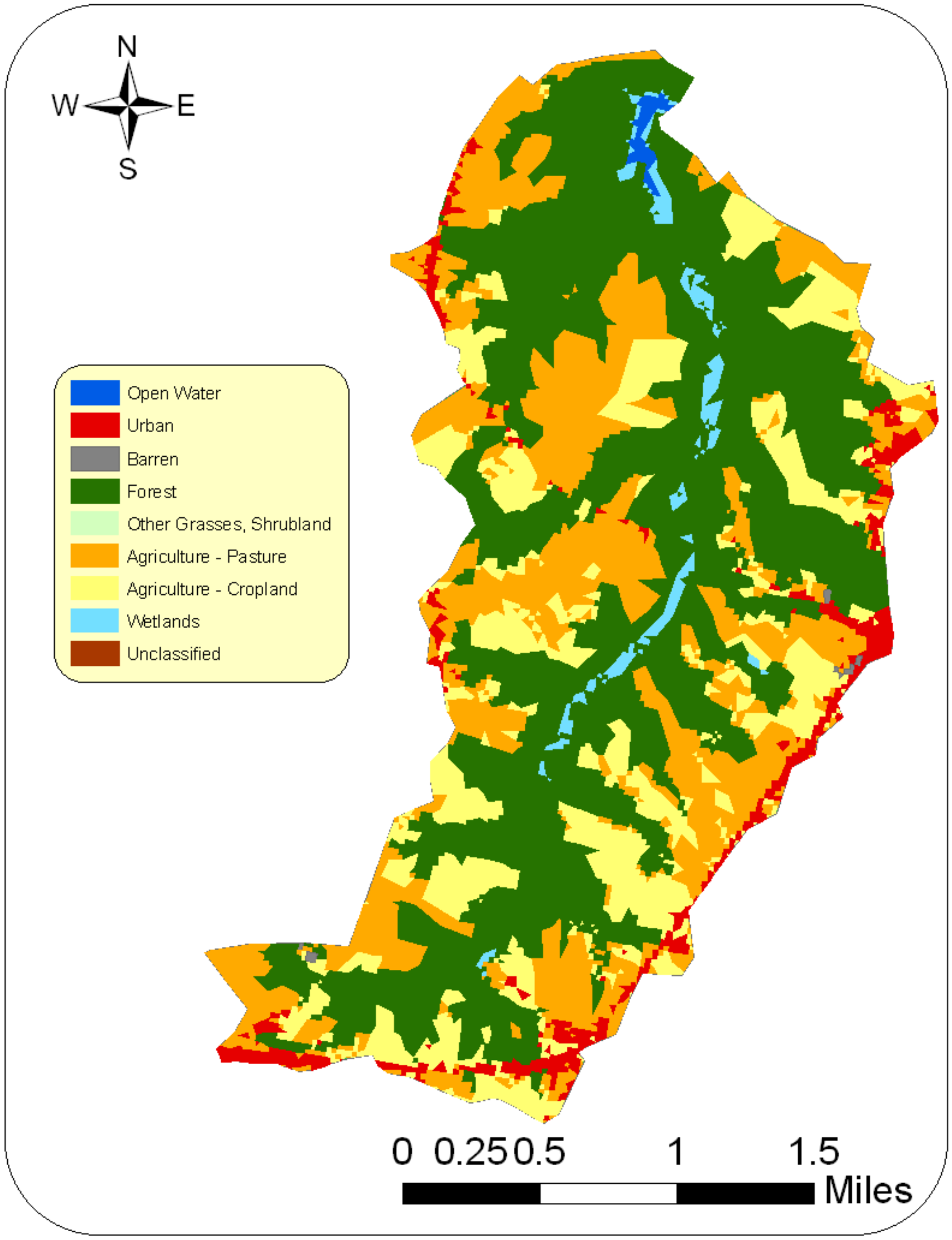

Figure 4. Land use in the Mill Creek watershed

3. Description of Water Quality Impairment

Mill Creek and its tributaries were listed as impaired on Virginia's 2002 303(d) Report on Impaired Waters (VADEQ 2003) due to violations of the State's water quality standards for fecal coliform bacteria at Route 202 (station 1AMIA004.12). Of the 28 fecal coliform bacteria samples collected at station 1AMIA004.12 from May 1996 to April 2001, 4 violated the water quality standards (14% violation rate). The extent of the 2002 impairment spanned from the headwaters downstream past Rt. 202 to the upstream end of Kissinger Millpond for a total of 3.94 impaired non-tidal stream miles. In 2003, VA DEQ switched from fecal coliform to *E. coli* as the indicator organism in non-tidal waters for the primary recreational use water quality standard. Monitoring conducted in preparation for this TMDL study (July 2008 to June 2009) indicated the bacteria impairment of Mill Creek was still present based on 3 *E. coli* violations out of 12 samples at station 1AMIA004.12 (25% violation rate).

Although the originally impaired downstream boundary lies above Kissinger Millpond, DEQ has included Kissinger Millpond and its unnamed tributary (UT) in the watershed for the purposes of this study. The collective watershed includes Mill Creek from its headwaters to the tidal limit just below Kissinger Millpond (also known as Courtney Millpond) dam, Kissinger Millpond, and UT to Kissinger Millpond. DEQ also monitored E. coli at the Rt. 620 bridge at the dam of Kissinger Millpond from July 2008 to May 2009 because this was the only other public access point on non-tidal Mill Creek. Of the 11 E. coli bacteria samples collected at station 1AMIA002.34, 2 violated the water quality standards (18% violation rate). Samples collected at station 1AMIA002.34 are not used in the development of the TMDL loads for Mill Creek; rather the station indicates that the bacteria impairment does extend to the tidal limit of the creek and that DEQ is justified in including UT to Kissinger Millpond and Kissinger Millpond in the TMDL report. The summary of bacteria water quality monitoring in the Mill Creek watershed are shown in Table 4.

Table 4. Bacteria data collected by DEQ at Mill Creek from May 1996 – June 2009

Station	Date of First Sample	Date of Last Sample	Number of Samples	Indicator Organism	Instantaneous Water Quality Standard* (cfu/100ml)	Number of Exceedances	Percent Violation**
1AMIA004.12	5/23/1996	4/4/2001	28	Fecal Coliform	1000	4	14%
	7/23/2008	6/17/2009	12	*E. coli*	235	3	25%
1AMIA002.34	7/23/2008	5/13/2009	11	*E. coli*	235	2	18%

*Exceedances of the then applicable instantaneous water quality standard of 1,000 cfu/100 ml until December 2002, and the 235 E. coli cfu/100 ml after January 2003.
**The instantaneous water quality standard allows a percent violation rate of up to 10.5% at a monitoring station, over which is considered a water quality impairment. Violation rate is calculated by dividing the number of exceedeances by number of samples.

A time series graph of all data collected at station 1AMIA004.12, illustrates the bacteria concentrations which ranged from 18 to 16,000 cfu/100 ml (Figure 5). The horizontal line at the 1000 cfu/100 ml fecal coliform instantaneous water quality standard and the 235 cfu/100ml E. coli water quality standard represents the applicable instantaneous fecal coliform water quality standards used in the 2002 and 2008 water quality assessments for the respective 303(d) reports. The data points above the 1000 cfu/100 ml fecal coliform instantaneous water quality standard and the 235 cfu/100 ml E. coli water quality standard lines represent violations of the respective applicable water quality standard. Figure 6 illustrates the time series graph for station 1AMIA002.34.

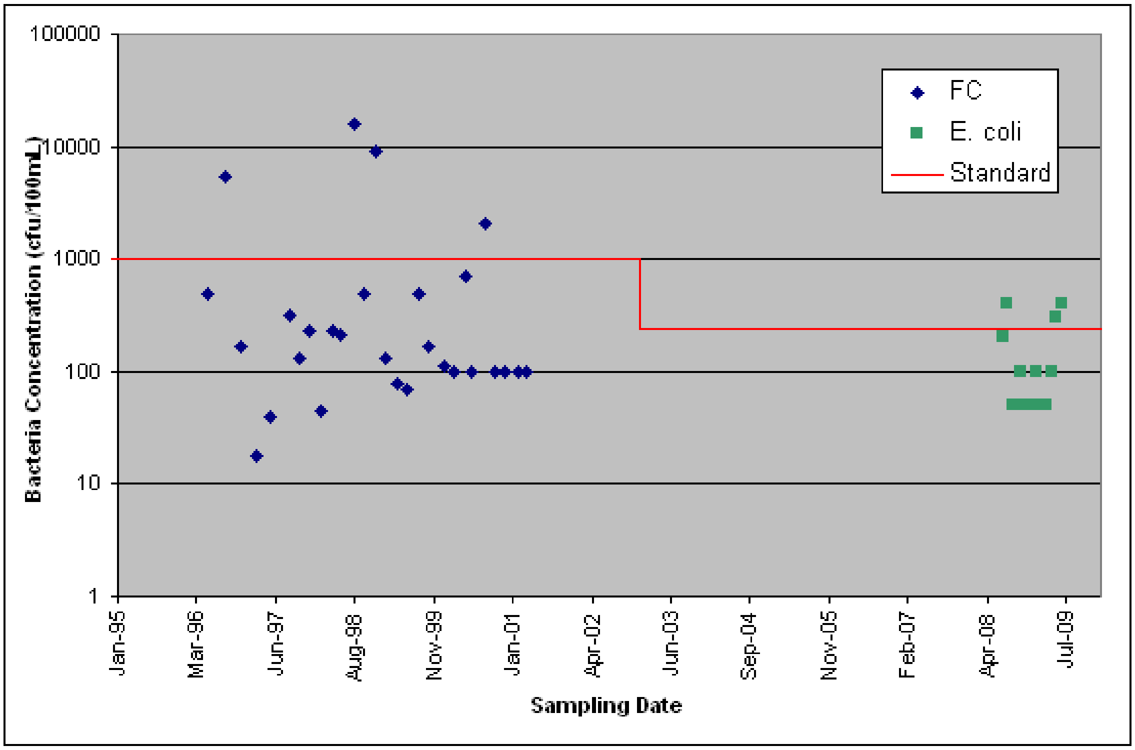

Figure 5. Time se ries of bacteria concentrations in Mill Creek (station 1AMIA004.12)

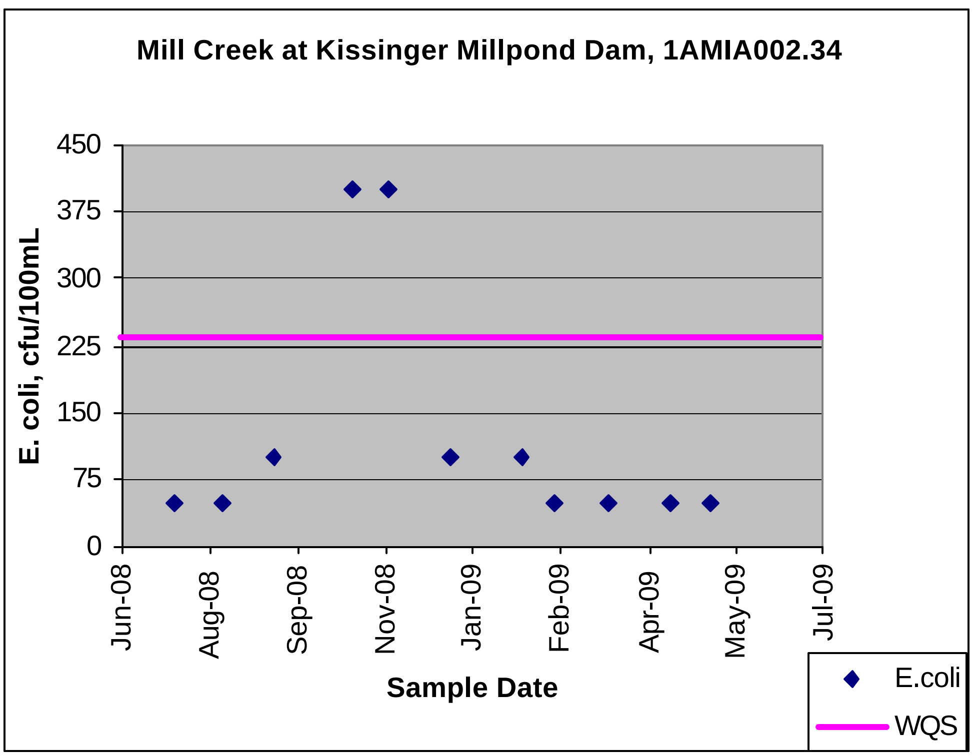

Figure 6. Time series graph of bacteria concentrations at Mill Creek (station 1AMIA002.34)

Figure 7 illustrates the number of bacteria samples and exceedances that were recorded for each month for Mill Creek (where the instantaneous water quality standard = 1000 fecal coliform cfu/100mL until Dec. 2002, or 235 E. coli cfu/100mL after Jan 2003). The graph shows that during months where violations were observed, 3 out of the 4 months were warm weather months. The percents which lie above the violation bars indicate the percent of time per month where samples violated the water quality standard.

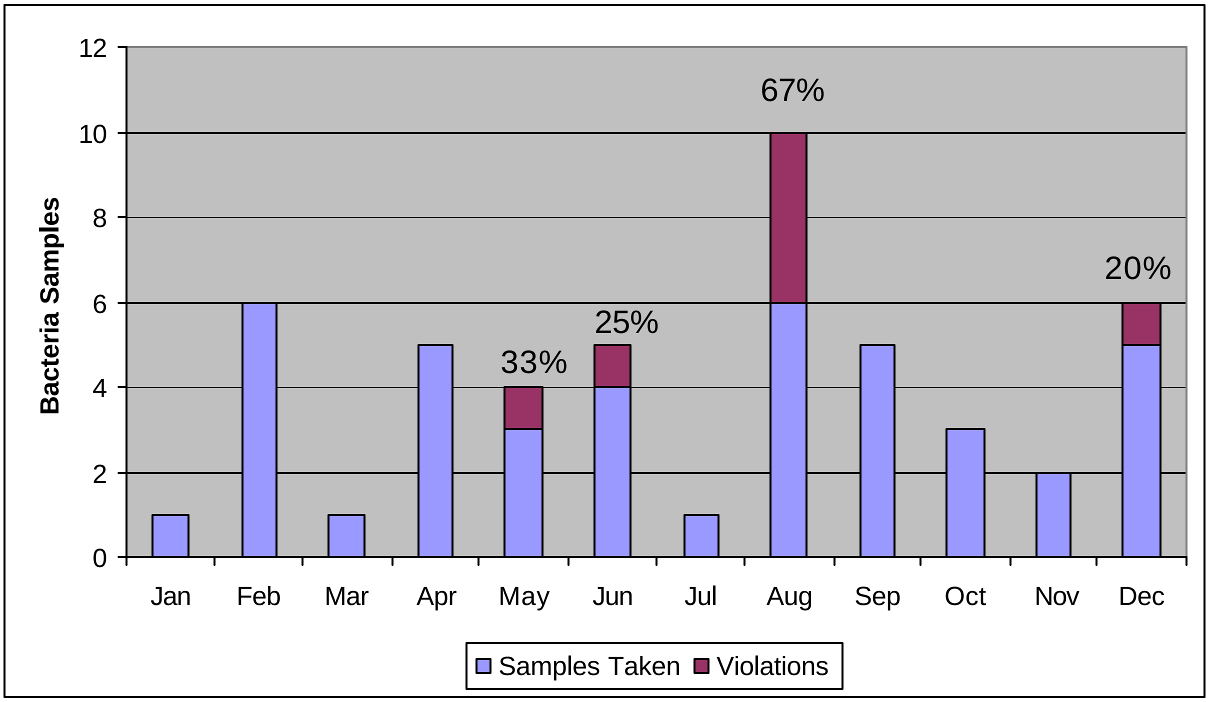

Figure 7. Monthly distribution of bacteria samples and violations in Mill Creek at station 1AMIA004.12

4. Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term *"water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

As stated above, Virginia water quality standards consist of a designated use or uses and water quality criteria. These two parts of the applicable water quality standard are presented in the sections that follow.

4.1. Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10A), *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

As stated above, Mill Creek must support all designated uses and meet all applicable criteria.

4.2. Applicable Water Quality Criteria

The applicable water quality criteria for bacteria in the Mill Creek watershed has changed since the initial listing on the 303(d) report. Following EPA recommendations, the Virginia Department of Environmental Quality (DEQ) proposed more stringent fecal coliform bacteria standards as well as new standards for *Escherichia coli* (*E. coli*) bacteria (Table 5). These new standards were adopted by the State Water Control Board in May 2002, public noticed in June 2002, approved by the USEPA in November 2002, and were effective January 15, 2003.

The EPA recommendation that states adopt *E. coli* and enterococci (saltwater) standards stems from a stronger correlation between the concentration of *E. coli* and enterococci organisms and the incidence of gastrointestinal illness. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. *E. coli* is a subset of fecal coliform group; thus a waterbody listed as impaired for fecal coliform is considered to be listed for *E. coli* as well.

Although Mill Creek was listed as impaired due to a violation of the previous fecal coliform standard, the TMDL must be developed to meet the new *E. coli* bacteria standard. The interim fecal coliform bacteria standard presented below will not apply to this TMDL since 12 *E. coli* bacteria samples were recently collected in preparation for the TMDL development.

New Bacteria Standards

For a non-shellfish supporting water body to be in compliance with Virginia bacteria standards for primary contact recreational use, the DEQ specifies the following criteria (9 VAC 25-260-170):

1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.

2. E.coli and enterococci bacteria per 100 ml of water shall not exceed the following:

Table 5. Applicable water quality standards

Parameter	Geometric Mean[1] (cfu/100 ml)	Single Sample (cfu/100 ml)
E.coli (fresh water)	126	235
Enterococci (saltwater & Transition Zone 3)	35	104

[1] for four or more samples taken during a calendar month.

If the waterbody exceeds the criterion as listed above in more than 10.5 percent of samples, the waterbody is classified as impaired and a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion. Based on the sampling frequency, only one criterion is applied to a particular datum or data set (9 VAC 25-260-170). If the sampling frequency is one sample or less per calendar month, the instantaneous criterion is applied; for a higher sampling frequency, the geometric mean criterion is applied.

For Mill Creek, the TMDL is required to meet the instantaneous criterion (235 cfu/100ml *E. coli*) since the load-duration approach used to develop the TMDL for Mill Creek yields the maximum allowable bacteria concentration under any given flow condition. Unlike a continuous time series simulation, the flow duration approach does not yield daily bacteria concentrations which are needed to apply the 30-day geometric mean standard. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect bacteria loading.

5. Assessment of Bacteria Sources

5.1 Source Assessment

The assessment of bacteria sources in traditional bacteria TMDL studies involves estimating loads from sources in the watershed and developing a computer model to establish the links between estimated loads and actual in-stream bacteria concentrations.

Load estimates are broken into point and non-point sources. It is important to note that the non-point source load estimates represent loading to the land surface of the watershed – thus available for run-off to streams; they are not estimates of in-stream loads.

In a load-duration bacteria TMDL, source assessment is accomplished by determining the relative contribution by source of the fecal bacteria contained in a sample of stream water. This method of source identification is achieved by estimating the source populations within the watershed and multiplying each total source type by its relative fecal bacteria per day production. This method of nonpoint source load allocation has been used in many TMDLs completed in Virginia (values used for sources by type in Appendix B). Management and remediation of water pollution will be cost effective if the correct sources are able to be correctly identified (Simpson, 2002).

5.2. Point Sources

Bacteria loading from point sources such as sewage treatment plants, small commercial establishments, schools, homes and businesses require permits under the Virginia Pollution Discharge Elimination System (VPDES) permit program. In order to consider all such point-source discharges in the Mill Creek watershed, the DEQ comprehensive environmental database, regional DEQ permit staff, and local Virginia Department of Health (VDH) offices were queried. Currently there are no VPDES Individual permits or Virginia Pollution Abatement (VPA) permits located within the Mill Creek watershed. There is one facility which holds a VPDES General Permit for Stormwater Industrial use: the Carry on Trailer Corporation (VAR051302). Stormwater industrial facilities are not typically assigned bacteria limits within their permits; therefore, this facility will not receive an *E. coli* waste load allocation (WLA) in the TMDL. The details regarding the permitted point source in the Mill Creek watershed is presented in Table 6.

Table 6. Point source facility in the Mill Creek watershed

Stream Name	Facility Name	VPDES Permit Number	Discharge Type[1]	Design Flow (MGD)	Permitted *E.coli* Limit (cfu/100 ml)
UT to Mill Creek	Carry On Trailer Corporation	VAR051302	Stormwater Industrial	NA[1]	NA[1]

[1]Criteria not applicable for this type of permit

Because no point sources with permitted bacterial limits exist in the Mill Creek watershed, the TMDL wasteload allocation (WLA) will be set at one (1) percent of the total load allocation to allow for future facility growth in the watershed.

5.3. Non-Point Sources

In order to gain an understanding of non-point source loading in the Mill Creek watershed, bacteria loads for typical non-point source categories were estimated. These estimates were based upon animal and human population data sets and typical waste production rates by source type.

Currently published values for fecal bacteria production rates are primarily in terms of fecal coliform. There is little data on *E. coli* production; however, studies have shown that though minor variability will exist between sources, *E. coli* represents roughly 90-95% of fecal coliforms contained in "as-excreted" fecal material (Yagow, 2002). This implies that the relative bacteria contribution by source should remain constant.

It is important to note that the bacteria loads presented in the following sections for non-point sources represent "as-produced" loads by source type. This is to say that some portion of an estimated load may not be available to be transported to Mill Creek in runoff. However, for the purposes of this report, 100% of fecal coliform production of non-point source types was assumed available for run-off. In addition, the values used for fecal coliform production are not meant to be used directly to calculate non-point source loadings in the watershed. Rather, they are used to calculate a relative percent contribution of fecal coliform, which is explained in Section 5.3.4 and Table 10.

5.3.1. Humans and Pets

Bacteria loading from human sources can come from straight pipes, failing septic systems, and land-applied biosolids. Failing septic systems are typically manifested by effluent discharging to the ground surface where the bacteria laden effluent is then available to be washed into a stream as run-off during a precipitation event. In contrast, discharges from straight pipes are typically directly deposited to streams.

In 2007, the Biosolids program was transferred from the Virginia Department of Health to the Virginia Department of Environmental Quality. All biosolids, or sludge, are the solids which result from the treatment of wastewater at a sewage treatment plant. The application of biosolids to land requires a permit from the DEQ. In areas within the Chesapeake Bay watershed, biosolids may only be spread within specified areas of land with appropriate offsets in accordance with the Chesapeake Bay Act and each field/farm must have a Nutrient Management Plan (NMP). Class “B” biosolids, which comprise the majority of all land applied biosolids, may not contain a fecal coliform density greater than 1,995,262 cfu/g (total solids) and application rates must be limited to a maximum of 15 dry tons/acre per three-year period. When applied properly, biosolids should not contribute a bacteria load to nearby streams. However, the potential exists for a portion of these fecal bacteria to be transported to a stream as run-off during storm events, when applied improperly.

Pets, primarily dogs, have the ability to contribute bacteria to the watershed when waste is left on the land and washed off during rain events. The presence of concentrated dog populations, such as the location of a kennel where many dogs may be confined, is of interest during TMDL development. Improper or inadequate disposal of dog fecal waste in proximity to a waterway can result in preventable bacteria exceedences of the water quality standard.

Straight Pipes

The local health department reported no known straight pipes in the Mill Creek Watershed.

Septic Systems

Based on the 2000 U.S. Census, there are approximately 2.24 people per household in Northumberland County. Using National Agriculture Imagery Program (NAIP) maps (USDA-FSA, 2009) ,152 “buildings” which by best professional judgment, were counted within the Mill Creek watershed and interpreted as homes. However there is a sewered portion of the Mill Creek watershed radiating out from Callao, VA along Rts. 360, 202 and 622. There are approximately 56 homes or commercial buildings along these corridors which are on the Callao wastewater collection system (http://www.co.northumberland.va.us/NH-Graphics/NH-callao-sewer.gif), which was confirmed from aerial photography. Therefore the number of buildings in the Mill Creek watershed on private septic systems was estimated to be 96 buildings (152 buildings total – 56 sewered buildings = 96 buildings on private septic systems). For the entire Mill Creek watershed, the human population is estimated at 340 residents (2.24 people per household X 152 homes = 340 residents).

Thus a fecal coliform contribution via failing or malfunctioning septic systems can be calculated. In 2000, a TMDL study by Virginia Tech enumerated a human fecal coliform load of 1.95E+09 cfu/person/day.

Surveys of failing septic systems in other Virginia watersheds have yielded a formula for calculating a rate of septic system failures for a given area. In the preparation of a TMDL report for the Goose Creek watershed in Loudoun County, VA, such a formula was used to estimate a septic system failure rate. The estimated failure rate was calculated to be as high as 17% for some portions of the county (ICPRB, 2002). In the absence of a septic system survey, the Goose Creek TMDL report specified a failure rate of 5% (ICPRB, 2002). This figure was based on the calculated failure rate, the professional judgment of the local health department, and results of a BST study completed for the Goose Creek watershed.

For this TMDL we assumed a 12% failure rate which was evaluated by the Virginia Department of Health (Northumberland County local health department) officials and was deemed reasonable for the watershed. Using the 12% failure rate multiplied by total number of buildings on private septic systems and number of people per household, the daily human load available as run-off to Mill Creek via failing septic systems was calculated as 5.27E+10 cfu/day, as shown in Table 7a.

Table 7a. Estimated daily fecal coliform contribution of failing septic systems in the Mill Creek watershed

Source	Estimated # Buildings on Septic Systems in Watershed	Estimated # Septic Failures in the Mill Creek Watershed (12% failure rate)	Number of People Estimated as Contributing to Septic Failures	Human Fecal Coliform Production Rate (cfu/person/day)	Total Estimated Fecal Production (cfu/day)
Failing Septic Systems	96*	12	27**	1.95E+09***	5.27E+10

*Number of buildings counted within the watershed using aerial photography from the National Agriculture Imagery Program (NAIP), 2008, in GIS, minus the number of buildings on munipal sewer collection in Callao.
**Calculated using the 2000 US Census value of 2.24 people per household multiplied by the number of estimated septic failures in the Mill Creek watershed.
***Production Rate as cited in by Geldrieich (1978) by VA Tech in the 2000 Fecal Coliform TMDL for Sheep Creek, Elk Creek, Machine Creek, Little Otter River, and Lower Big Otter River in Bedford and Campbell Counties, Virginia.

Biosolids

Annual biosolid application reports on file with DEQ revealed that there are three parcels permitted to receive biosolid applications within the Mill Creek watershed. These parcels received applications in 2004 only. The total net acreage which received biosolid applications was approximately 75 acres as reported by the applicator (see Table 7b below). The applications occurred during the dates of 3/22/04 - 3/29/04, 4/5/04 – 4/6/04, and 5/10/04 – 5/11/04. All the biosolids were lime-stabilized, thus low viable fecal coliform bacteria should be expected however Class B biosolids are permitted to contain fecal coliform bacteria up to 2,000,000 cfu / gram dry weight. Therefore, biosolids do not receive waste load allocations (WLAs) in TMDL reports.

Table 7b. Mill Creek watershed biosolid applications

Stream	Dates of Application	Dry Tons Applied	# Fields receiving application	Total Application Acres
Non-Tidal Mill Creek	3/22/04 – 3/29/09	336	5	75
	4/5/04 – 4/6/10	102	1	
	5/10/04 – 5/11/04	48	1	
Total		486	7	

Pets

Cats are estimated to have approximately one fifty-thousandth of the fecal coliform density of dogs, and thus are deemed insignificant in pet fecal bacteria production. Only dog source contributions are considered for the purposes of this TMDL report. The number of dogs in the watershed was calculated using the estimated number of households (152) multiplied by 0.632 (AVMA , http://www. avma.org/ reference /marketstats/ownership.asp#formulas) which resulted in a total of 96 dogs in the Mill Creek watershed. Using the waste production rates and fecal coliform densities from the Bacteria TMDL for the Virginia Coastal Area (MapTech, 2005), the total bacteria load contribution from dogs in the Mill Creek watershed is calculated as 2.07E+10 cfu/day. Table 7c presents the calculation of pet loads in the watershed. It should be noted that the numbers presented in Table 7c represent loads available for run-off and not in-stream loads.

Table 7c. Estimated daily fecal coliform contribution of dogs in the Mill Creek watershed

Source	Population	Dog Fecal Coliform Contribution (cfu/animal/day)	Total Dog Fecal Coliform Contribution to Mill Creek watershed (cfu/day)
Dog	96	2.16E+08*	2.07E+10

*Production Rate for dogs calculated using a waste load (g/an-day) of 450 (Weiskel et. al, 1996) and FC Density of 480,000 cfu/g (MapTech, 4/2002)

5.3.2. Livestock

Fecal matter from livestock can be deposited directly to the stream in instances where livestock have stream access, or the fecal matter can be transported to the stream in surface runoff from grazing or pasture lands.

The predominant type of livestock in the Mill Creek watershed is cattle, although all types of livestock were considered in developing the TMDL. The Mill Creek watershed is located entirely within Northumberland County and approximately 26.7% of its watershed is pasture land. Table 8 presents the livestock population estimates, fecal production rates, and estimated daily fecal production by source animal in the watershed. The livestock populations were first calculated by the Virginia Institute for Marine Science - Centers for Coastal Resource Management (VIMS -CCRM) who used National Agricultural Statistics Service, United States Department of Agriculture Data (USDA, 1997/2001) to calculate livestock populations based on land use type per subwatershed. The livestock numbers were verified and corrected by the local Soil and Water Conservation District (SWCD) and the local extension agency. Cattle total is by direct visual count by DEQ staff.

Table 8. Estimated fecal coliform production of livestock in the Mill Creek watershed

Source	Population	Livestock Fecal Coliform Production Rates (cfu/animal/day)	Total Livestock Fecal Coliform Production in Mill Creek watershed (cfu/day)
Cattle	50	3.30E+10*	1.65E+12
Goats	5	2.70E+10**	1.35E+11
Horses	4	4.20E+08***	1.68E+09
Chickens	30	1.36E+08****	4.08E+09
Total			1.79E+12

*Assumption that all are “beef” cattle. Production rate is based on data presented by Metcalf and Eddy (1979) and ASAE (1998)

**Goats were assumed to have the same fecal coliform density as Sheep and were reported by Maptech (2/2000). Waste load presented by ASAE (1998)
***Production rate presented by ASAE (1998)
****Assumption that all chickens are “layers”. Production rate is presented by ASAE (1998)

5.3.3. Wildlife

Like livestock, fecal matter from wildlife can be either deposited directly to the stream, or it can be transported to the stream in surface runoff from woods, pastureland and cropland. Direct deposition to streams varies with species, e.g. beaver spend most of their time in water; therefore most of their fecal matter would be directly deposited to the stream.

The livestock populations were first calculated by the Virginia Institute for Marine Science - Centers for Coastal Resource Management (VIMS -CCRM) who used the Department of Game and Inland Fisheries density estimates for each animal type based land use and habitat suitability. The estimates were presented during the first public meetings and adjustments were made based on observations of DEQ personnel and citizens of the watershed. Table 9 below, shows the Mill Creek watershed total wildlife fecal coliform contribution to be 1.08E+11 cfu/day.

Table 9. Estimated fecal coliform production from wildlife in the Mill Creek watershed

Source Type	Population Estimate	Fecal Coliform Production Rate (cfu/animal/day)	Total Wildlife Fecal Coliform Production Rate (cfu/day)
Deer	75[1]	3.47E+08[5]	2.60E+10
Muskrat	770[2]	2.50E+07[5]	1.93E+10
Beaver	2[4]	2.00E+05[6]	4.00E+05
Raccoon	112[1]	1.13E+08[5]	1.27E+10
Goose	50[3]	7.99E+08[5]	4.00E+10
Swan	4[4]	2.43E+09[7]	9.72E+09
Total			1.08E+11

[1]Estimates calculated by CCRM-VIMS (2003)
[2]Estimate calculated using DGIF density for muskrat where 10 animals/acre in wetland/marsh/pond/lake-edge habitat
[3]Observation by DEQ personnel in Fall 2008
[4]Observation by landowner by Kissinger Millpond
[5]Yagow (1999)
[6]Maptech (12/2000)
[7]Maryland Department of the Environment (2006) Rate assumed to be equal to duck (duck rate based on USEPA 2000)

5.3.4 Relating Non-point Source Fecal Coliform Contributions to Load Duration Values

In order to attribute the loads by source type into a load allocation (LA) for the TMDL, the calculated fecal coliform productions (cfu/animal/day) had to be related to the calculated load duration values for the current and total TMDL loads. This was done by summing the 4 non-point source type categories for fecal coliform production and then calculating the percent contribution of each source type to the total. The percent equivalent of the non-point source type fecal coliform production values are shown in Table 10

Table 10. Mill Creek watershed non-point source daily fecal coliform contribution (cfu/day)

Non-Point Source Fecal Coliform Production Totals (cfu/day)		Percent Equivalent
Livestock	**1.79E+12**	**90.82%**
Domestic Pet	**2.07E+10**	**1.05%**
Wildlife	**1.08E+11**	**5.46%**
Human	**5.27E+10**	**2.67%**
Total	**1.97E+12**	**100.00%**

With the relative percent contribution for each source type calculated, the percents were used to calculate the current load, load allocation, and reductions needed for each source type, using the load duration derived current and total TMDL loads. The percent equivalents noted in Table 10 were used to calculate the load allocations in Section 7, Tables 15 and 16.

6. TMDL Development

One of the major obstacles to improving stream water quality is that the potential sources of bacteria are numerous and the dominant sources and/or pathways are generally unknown. This can make it difficult to direct effective cleanup efforts.

Typical pathogen TMDLs are completed by developing watershed-based computer simulations that establish links between sources and in-stream water quality. While effective, the effort required to develop modeled TMDLs can be costly. In an effort to complete pathogen TMDLs in a timely and cost-effective manner, the use of load-duration analyses has been investigated. It has been determined that the load-duration method of calculating a TMDL produces a result only slightly more conservative than if the TMDL had been determined through computer modeling.

The load duration method essentially uses an entire stream flow record to provide insight into the flow conditions under which exceedances of the water quality standard occur. Exceedances that occur under low flow conditions are generally attributed to loads delivered directly to the stream such as straight pipes and livestock with access to the stream. Exceedances that occur under high flow conditions are typically attributed to loads that are delivered to the stream in stormwater runoff. Exceedances occurring during normal flows can be attributed to a combination of runoff and direct deposits.

The following sections detail the development of the load-duration TMDL and associated allocations.

6.1. Load-Duration Curve

Development of a load-duration curve begins with a flow-duration curve, and in order to develop a meaningful flow-duration curve one must have several years of flow data for the target stream or river. Where very little flow data exists for a target stream, a reference stream with the requisite flow measurements must be used similar to the paired watershed approach used in watershed-based modeling. Such is the case for Mill Creek.

The following sections detail the flow data for Mill Creek, the selection of a reference stream, development of a flow-duration curve for Mill Creek, and the creation of a load-duration curve for Mill Creek.

6.1.1. Flow Data

Mill Creek is located in Northumberland County and has a drainage area of 5.2 square miles and is a minor tributary to the South Yeocomico River. There is no continuous flow gaging station on Mill Creek, therefore a reference gaging station must be selected.

6.1.2. Reference Stream

In order to develop a flow-duration curve for Mill Creek, it was necessary to select a reference stream with a gage having a period of record of no less than ten years.

In selecting a reference gauge several factors must be considered. Among these are proximity, watershed topography, watershed size and geology. The period of record for the reference gage must also include dates that coincide with flow measurements made at the target stream - in this case Mill Creek. The ultimate goal is to find a gaged stream that behaves like the target stream.

For the Mill Creek analysis Aquia Creek near Garrisonville, VA (#01660400), Piscataway Creek near Tappahannock, VA (#01669000), Chopawamsic Creek (middle branch) near Dumfries, VA (#01659500), and Totopotomoy Creek near Studley, VA (#01673550) were considered as possible reference gages. Totopotomoy Creek had the strongest correlation with an R value of 0.9841; however this stream is a tributary to the Pamunkey River and lies approximately 35 miles southwest of Mill Creek. Piscataway Creek, which is a tributary to the Rapphannock River, was determined to be the best reference stream due to its strong correlation (R value of 0.9819), similar land use, and its location of within 16 miles of Mill Creek. Details of the correlation analysis and reference stream selection are presented in Appendix D.

6.1.3. Flow-Duration Curves

In order to use the load-duration method to develop a TMDL, a flow-duration curve must be developed for the impaired stream. This is accomplished by first developing a flow-duration curve for the reference Piscataway Creek gage. To generate a flow-duration curve for Mill Creek, the Piscataway Creek flows corresponding to the percentiles 1%, 5%, 10%…90%, 95%, 99% were plugged into the regression equation ($y=0.5792x^{0.4932}$) obtained from the flow regression plotted for Mill Creek. This allowed the generation of a full set of flows for Mill Creek. The generated flows were plotted against the percentiles mentioned above, and a flow duration curve was drawn for Mill Creek (Figure 8).

A flow-duration curve is a plot showing the flow magnitude (cfs) along the "y" axis and the frequency of daily average stream flow (%) along the "x" axis. For example, the flow value corresponding to “1%” is the flow that has been exceeded only 1% of the time for which measurements exists. Likewise, the flow value corresponding to “30%” is the flow that 30% of the historic record exceeds.

To plot the flow values for the period of record of the reference stream, the PERCENTILE statistic function of Excel was used. The resulting percentile of a given flow was then subtracted from 1 to yield the percent of time that a given flow is exceeded by the flows of record. The flow duration interval values were plotted with the corresponding flows to yield a log/normal flow duration curve.

The flow-duration curve for Mill Creek has been divided into four sections to help illustrate flow conditions. These sections are titled "High Flows", "Transition Flows", "Normal Flows", and "Low Flows". Low flows can be roughly equated to near-drought or drought flows. High flows are near-flood or flood flows. Transition flows are, as implied, neither normal nor high.

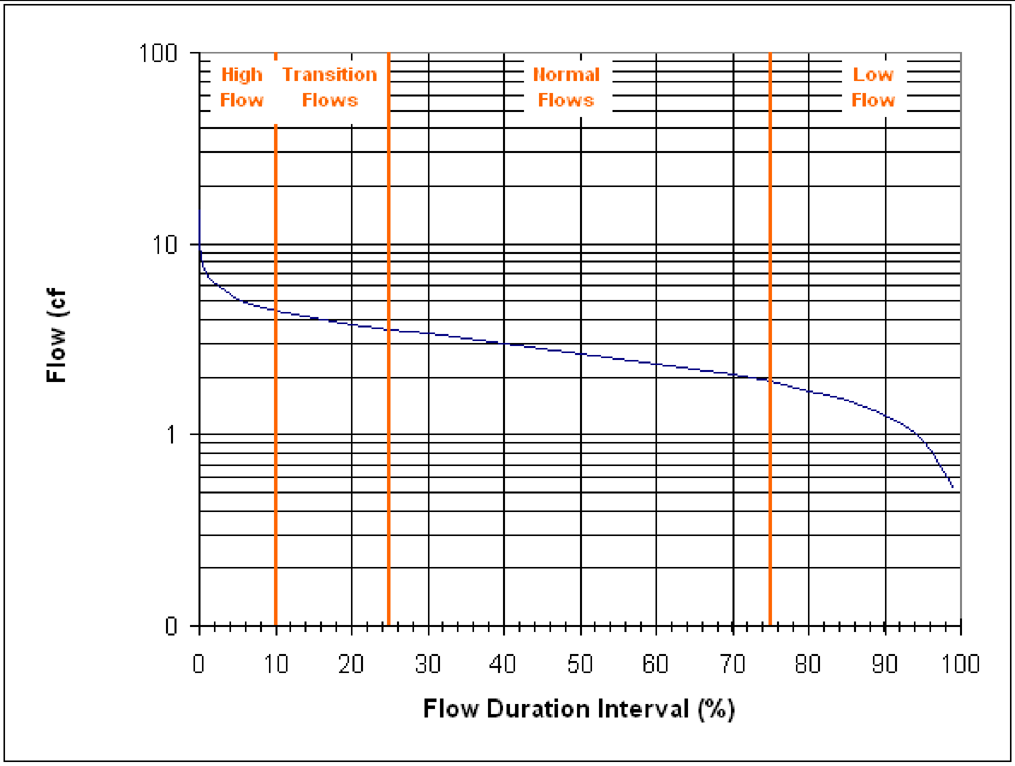

Figure 8. Flow-duration curve for Mill Creek at Route 202, near Callao, VA (station 1AMIA004.12). Flows are shown in cubic feet per second (cfs)

6.1.4. Load-Duration Curve

As mentioned in Section 3, all of the instream water quality observations on Mill Creek which resulted in the initial impairment listing were collected at Station 1AMIA004.12, therefore this station is the focus of the load-duration analysis on Mill Creek.

A load-duration curve is developed by multiplying each flow level along the flow-duration curve by the applicable water quality standard and required unit conversions. The resulting curve represents the maximum allowable load at each flow level, in other words, the Total Maximum Daily Load (TMDL). Each water quality observation is then assigned to a flow interval by comparing the date of each water quality observation to the flow record of the reference stream. The reference stream flow from the date of the water quality observation is then used to calculate a stream flow and flow-duration interval for the target stream.

In previous TMDLs using this methodology, the curve was transformed from daily loads to annual loads by multiplying each point along the curve by 365. Although EPA only requires the report of daily loads, yearly loads are useful in terms of implementation planning; therefore both daily and yearly tables are shown.

In order to plot existing fecal coliform (FC) data against the *E. coli* (EC) standard/TMDL line, it was necessary to translate the FC data to EC data. Translation of FC data to EC data was achieved by using a translator equation developed from a regression analysis of 493 paired FC/EC data sets from the DEQ's statewide monitoring network. The translator equation resulting from the regression analysis is presented below:

$$\textbf{EC } \log_2 = -0.0172 + 0.91905 * \textbf{FC } \log_2$$

This translator equation may cause a slightly different number of water quality standard violations as shown in Figure **5** versus bacterial load exceedances as shown in Figure **7**. This is because of the variance of the translator equation related to specific fecal coliform results near the water quality standard.

By plotting these observed loads on the load-duration curve, the number and pattern of exceedances of the water quality standard (TMDL) can be analyzed. The load duration curve and observed data for Mill Creek are shown in Figure **9**. The TMDL line has been plotted for the instantaneous *E. coli* standard of 235 cfu/100mL.

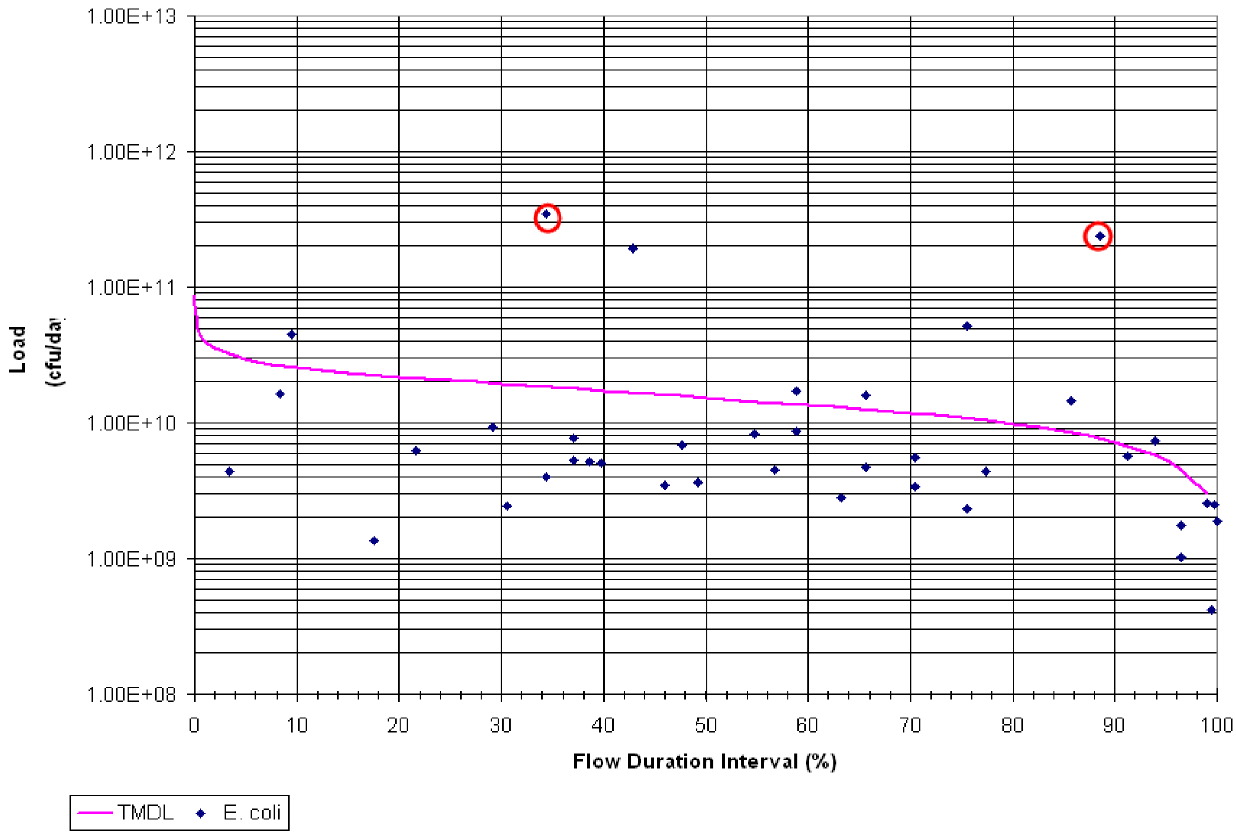

Figure 9. Daily Load-duration curve and water quality data for Mill Creek at station 1AMAI004.12. E coli load is shown in cfu/day

Figure 9 suggests that exceedances of the water quality standard occur under all flow conditions. The highest exceedances of the water quality standard occurred at low flow (89% flow interval at 1.35 cfs) and normal flow (34% flow interval at 3.25 cfs) circled in red in Figure 9. These represent the flow conditions under which the largest bacteria reduction is required in order to meet water quality standards. The translated load at the low flow condition was 2.39E+ 11 cfu/day and at the normal flow condition was 3.45E+11 cfu/day. Under the instantaneous *E. coli* standard of 235 cfu/100mL, the load of the low flow condition would have to be reduced by 97% to an allowable load of 7.79E+09 cfu/day at low flow. The load of the normal flow condition would have to be reduced by 95% to an allowable load of 1.87E+10 cfu/day. As is evident in Figure 9, the allowable daily load is variable with flow along the curve and represents simply the *E. coli* standard multiplied by the applicable flow condition and the proper unit conversions. Figure 10 shows the load duration curve for the *E. coli* load in cfu/year. Figure 10 shows that the low flow condition would have to be reduced by 97% to an allowable load of 2.84E+12 cfu/year and the normal flow condition would have to be reduced by 95% to an allowable load of 6.82E+12 cfu/year. Full calculations with unit conversions are presented in Appendix C.

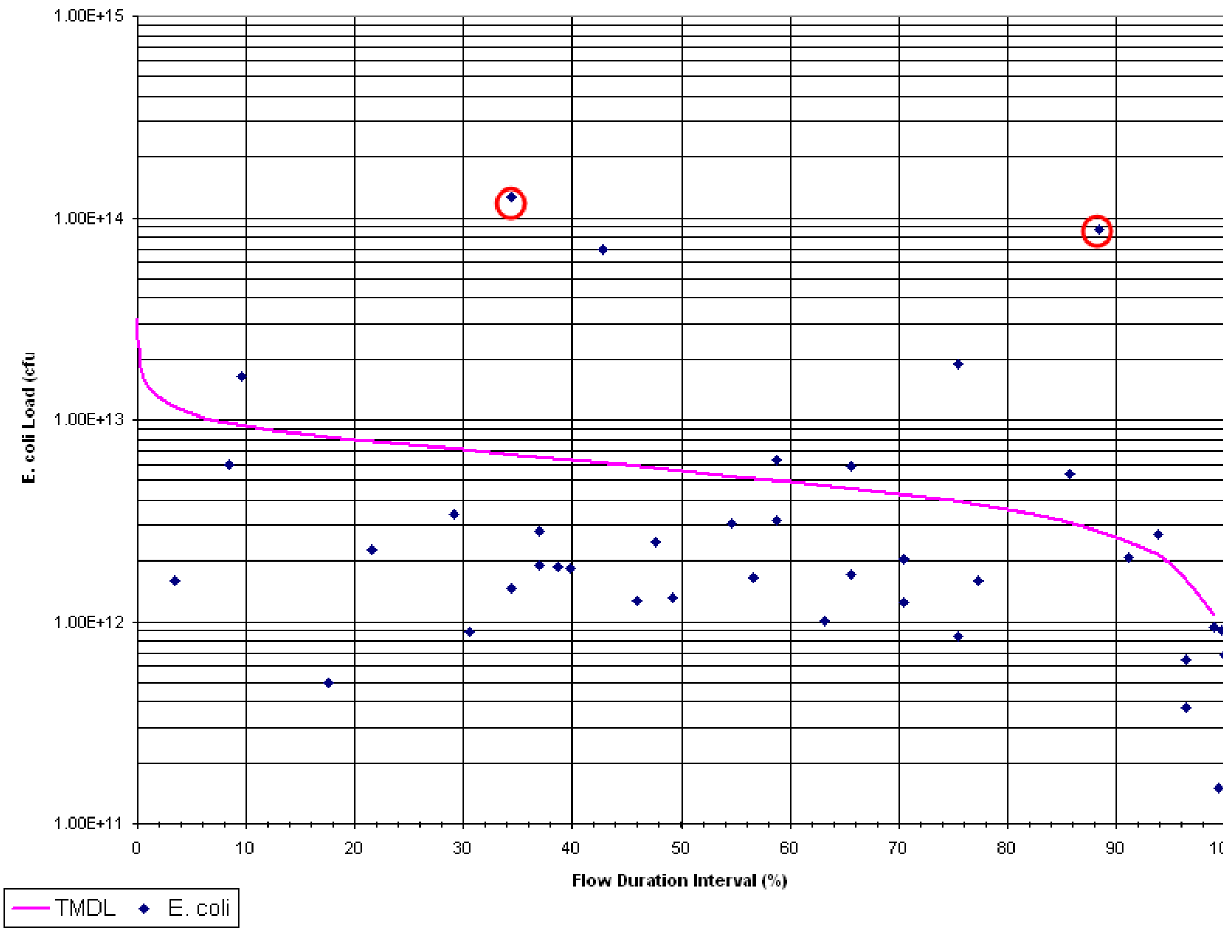

Figure 10. Annual Load-duration curve and water quality data for Mill Creek at station 1AMAI004.12. E coli load is shown in cfu/year

Because the allowable load is variable with flow and represents simply the *E. coli* standard multiplied by the applicable flow condition and the proper unit conversions, the TMDL condition will be selected to reflect the flow-varying nature of bacteria impairments. In order to capture all flow conditions, the TMDL will be determined for the 99th load percentile, i.e. for the 1% flow duration interval. This represents the maximum flow condition determined for Mill Creek from available flow records. To determine the necessary load reduction at this maximum flow condition, a second curve must be drawn through the highest exceedance described above. The second curve represents the magnitude of the highest observed exceedance if it were to occur over any flow condition. The graph of the load-duration curve with the maximum - exceedance curve is presented in Figure 11 for Mill Creek in cfu/day. Figure 12 shows the maximum – exceedance curve in cfu/year.

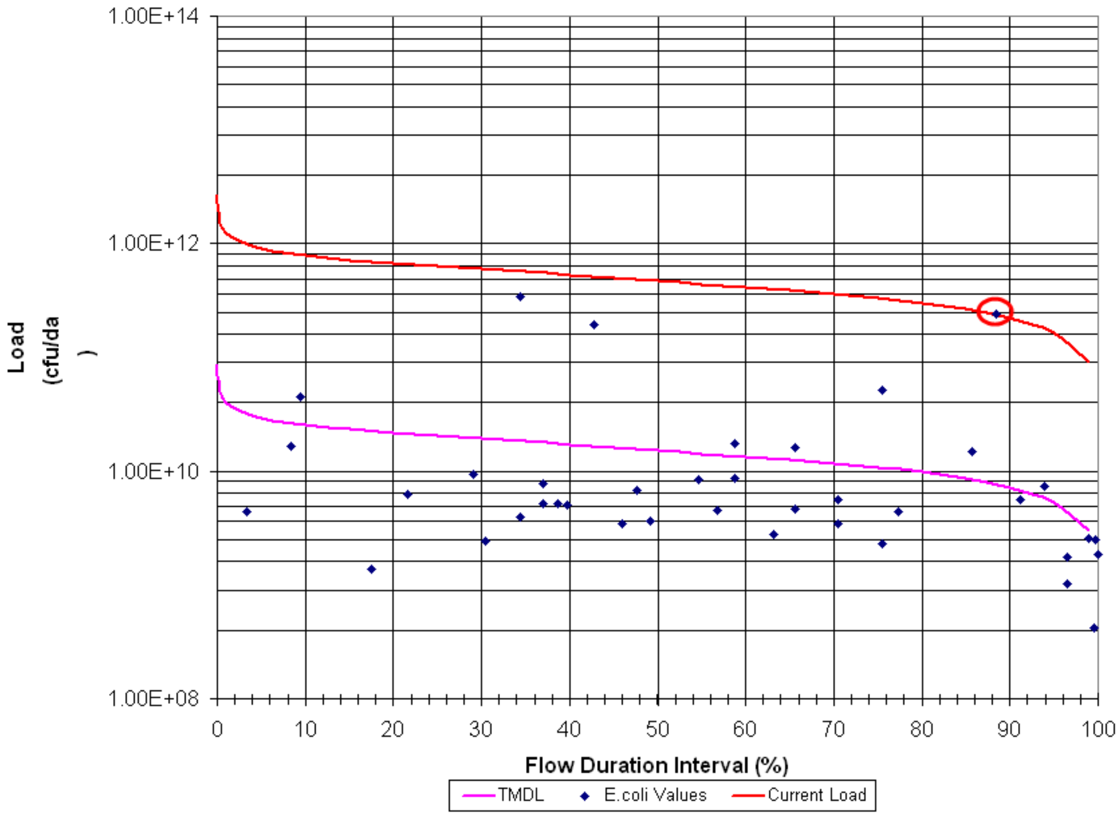

Figure 11. Daily Load-duration curve with maximum exceedance for Mill Creek at station 1AMIA004.12 (cfu/day)

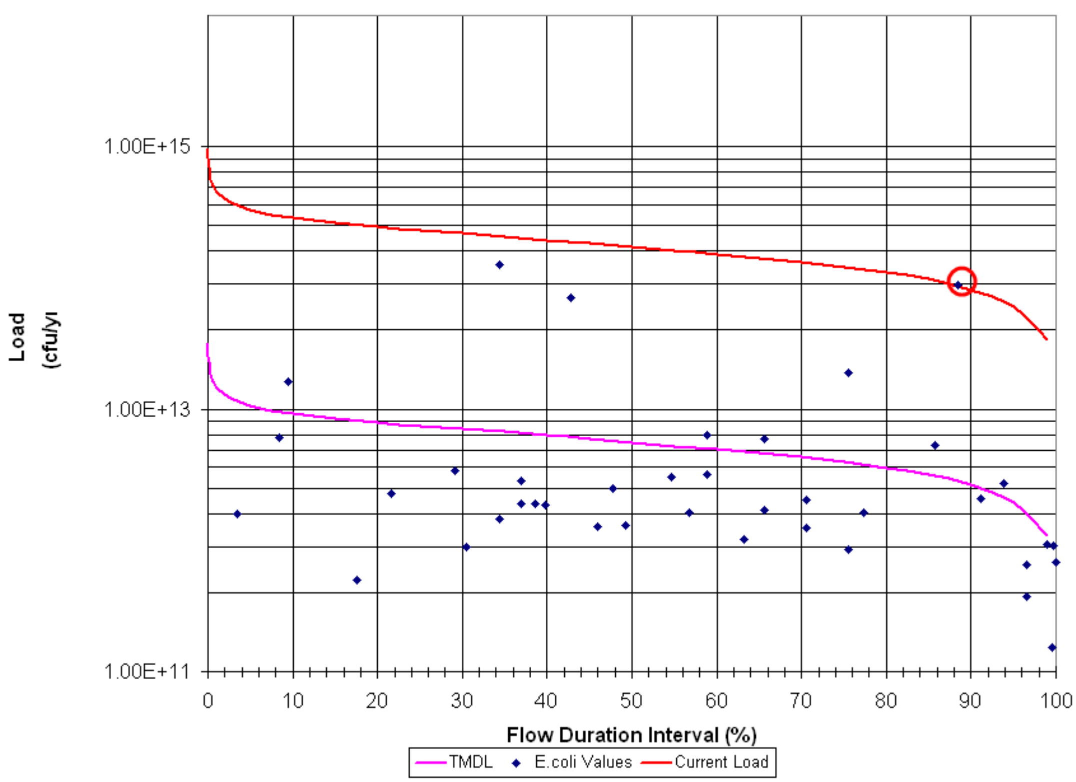

Figure 12. Annual Load duration curve with maximum exceedance for Mill Creek at station 1AMIA004.12 (cfu/year)

6.2 TMDL

A Total Maximum Daily Load (TMDL) consists of 1) point source/waste load allocations (WLAs), 2) non-point sources/load allocations (LAs) where the non-point sources include natural/background levels, and 3) a margin of safety (MOS) where the margin of safety may be implicitly or explicitly defined. TMDLs contain an expansion factor for growth of existing or new point source WLAs. This TMDL definition is typically illustrated by the following equation:

TMDL = WLAs (including 1% Future Growth Factor) + LAs + MOS

Simply put, a TMDL is the amount of a pollutant that can be present in a waterbody where the waterbody will still meet water quality standards for that pollutant. In the case of load-duration bacteria TMDLs, the TMDL is expressed as the total number of colony forming units (cfu) per day for the 99th load percentile.

The 1% flow duration for Mill Creek is calculated from the regression equation:

$$y=0.5792x^{0.4932}$$

and the 1% flow duration from the reference gage. The estimated 1% flow duration for Mill Creek is 6.9 cfs. This flow value is the 99th% highest estimated flow for Mill Creek. From this information an average daily *E. coli* load and TMDL can be calculated from the max-exceedance and TMDL curves. This is represented graphically in Figure 13 in cfu/day. The average annual E. coli load and TMDL are shown in Figure 14 (cfu/year). Full calculations are presented in Appendix C.

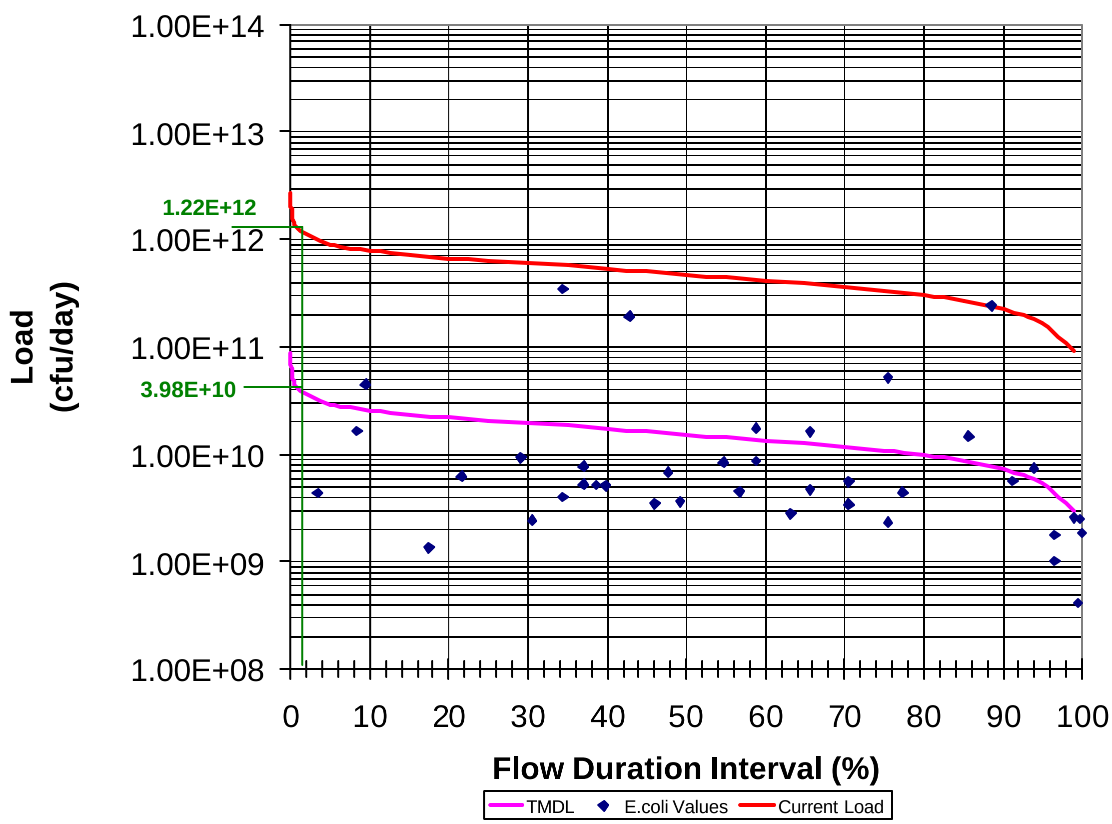

Figure 13. Daily Load-duration curve illustrating the TMDL and estimated current daily *E. coli* load for Mill Creek at station 1AMIA004.12

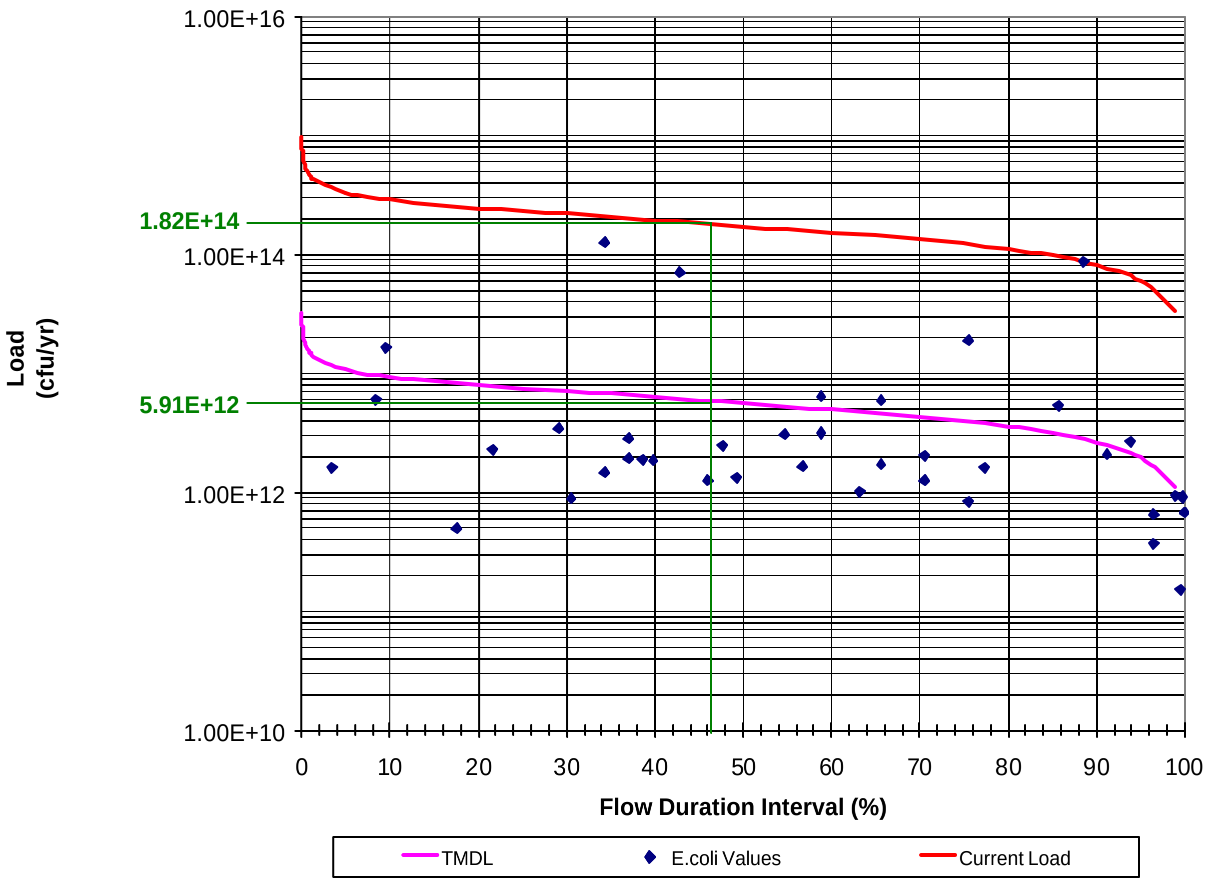

Figure 14. Annual Load-duration curve illustrating the TMDL and estimated annual *E. coli* load for Mill Creek at station 1AMIA004.12

For Mill Creek, the one percent flow duration current daily *E. coli* load is 1.22E+12 cfu/day, and the daily TMDL load under one percent flow duration is 3.98E+10 cfu/day. The average flow duration current annual E. coli load is 1.82E+14 cfu/year, and the annual TMDL load under the average flow duration is 5.91E+12 cfu/year. These values are used to calculate required reductions. Although there are no point sources with bacterial permit limits in either watershed, it is reasonable to assume future growth will occur. For this reason, a wasteload allocation (WLA) is set for one (1) percent of the total load allocation. This equals a daily load of 3.98E+08 cfu/day and an annual load of 5.91E+10cfu/year . The remaining load allocations (LA) address allowable non-point source bacterial contributions.

The TMDL, WLA and LA are presented as daily loads in Table 11 for Mill Creek. The annual loads are presented in Table 12.

Table 11. Average Daily *E. coli* loads and TMDL for Mill Creek watershed (cfu/day)

WLA[2]	LA	MOS	TMDL[1]
3.98E+08	**3.94E+10**	Implicit	**3.98E+10**

1 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.
2 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Table 12. Average Annual *E. coli* loads and TMDL for Mill Creek watershed (cfu/year)

WLA[2]	LA	MOS	TMDL[1]
5.91E+10	**5.85E+12**	Implicit	**5.91E+12**

1 – The annual TMDL is presented for the average annual flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.
2 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

7. Allocations

Reduction

The daily TMDL and *E. coli* load values from section 6.2, together with the one percent WLA for future expansion in the watersheds, were inserted into Table 13 below to determine the required reduction in bacteria loads. Since the required reductions will only apply to the non-point sources, the LA value was used to calculate the required percent reductions. Table 13 shows the required LA reductions in cfu/day and Table 14 shows the LA reductions in cfu/year for Mill Creek. Full calculations are presented in Appendix C.

Table 13. Daily TMDL and required reduction for Mill Creek

Allowable Loads (cfu/day)		**Current *E. coli* Load (cfu/day)**	**Required % Reduction**
TMDL (daily)[1]	**3.98E+10**		
Wasteload Allocation (WLA)[2]	3.98E+08		
MOS	Implicit		
Load Allocation (LA)	**3.94E+10**	**1.22E+12**	**97%**

1 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.
2 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Table 14. Annual TMDL and required reduction for Mill Creek

Allowable Loads (cfu/year)		Current *E. coli* Load (cfu/year)	Required % Reduction
TMDL (annual)[1]	**5.91E+12**		
Wasteload Allocation (WLA)[2]	**5.91E+10**		
MOS	Implicit		
Load Allocation (LA)	**5.85E+12**	**1.82E+14**	**97%**

1 – The annual TMDL is presented for the annual average flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable along the TMDL curve depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.
2 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Margin of Safety

This requirement is intended to add a level of safety to account for any inherent uncertainty in the TMDL development process and the data used in the development. The MOS may be either implicit or explicit. An implicit margin of safety relies on the conservative nature of the assumptions, values, and methods used to calculate a TMDL whereas an explicit margin of safety is a value (typically a percentage) applied at some point during the TMDL calculation.

In the Mill Creek TMDL, an implicit MOS was incorporated through the use of conservative analytical assumptions. These include: (1) the use of the single-most extreme water quality violation event which was used to develop maximum exceedance curve over the entire range of flow conditions, and (2) the computation of average annual load using the average flow conditions. Additionally, the load duration method of TMDL development has been evaluated against TMDLs that were developed using computer modeling. The results showed the load duration method to be slightly more conservative.

Allocations

In order to apply the reductions calculated above, the daily non-point source *E. coli* loads had to be allocated to each of the four non-point source categories of human, pet, livestock, and wildlife, which were detailed in Section 5.3. By applying the relative percent contribution by source (see Table 10), it is possible to derive the current non-point source loads based on the output of the load duration model for total current load. Table 15 below illustrates the distribution of the daily *E. coli* load among sources (derived by multiplying the daily load allocation by the fecal production of each source type for each of the four source groups), the reduction applied to each source, and the allowable loading for each source, for Mill Creek. Theoretically these reductions would reduce the *E. coli* load to the water quality standard, resulting in zero violations. For the purposes of implementation planning where improvements are reviewed on a larger time scale, these values are shown in cfu/year in Table 16.

Table 15. Daily load allocation and reductions needed by fecal type for Mill Creek

Impaired Waterbody	Fecal Type	Allocation % of Total Load	Current Load *E. coli* (cfu / day)	Load Allocation E. coli (cfu / day)	Reduction Needed
Mill Creek VAP-A33R-01-BAC	Wildlife	5.46%	6.66E+10	3.94E+10	41%
	Human	2.67%	3.26E+10	0.00E+00	100%
	Livestock	90.82%	1.11E+12	0.00E+00	100%
	Pets	1.05%	1.28E+10	0.00E+00	100%
	Total	**100.00%**	**1.22E+12**	**3.94E+10**	**97%**

Table 16. Annual load allocation and reductions needed by fecal type for Mill Creek

Impaired Waterbody	Fecal Type	Allocation % of Total Load	Current Load *E. coli* (cfu / year)	Load Allocation *E. coli* (cfu / year)	Reduction Needed
Mill Creek VAP-A33R-01-BAC	Wildlife	5.46%	9.91E+12	5.85E+12	41%
	Human	2.67%	4.85E+12	0.00E+00	100%
	Livestock	90.82%	1.65E+14	0.00E+00	100%
	Pets	1.05%	1.91E+12	0.00E+00	100%
	Total	**100.00%**	**1.82E+14**	**5.85E+12**	**97%**

7.1. Consideration of Critical Conditions

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Mill Creek is protected during times when conditions are most conducive for water quality criteria exceedances.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards. The sources of bacteria for Mill Creek are a mixture of low and normal flow-driven sources. TMDL development utilizing the load-duration approach applies to the full range of flow conditions; therefore, the critical conditions for Mill Creek were addressed during TMDL development.

7.2. Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality as a result of hydrologic and climatological patterns. The load-duration approach allows the pattern of water quality exceedances to be examined for seasonal variations. The load-duration method used to develop this TMDL implicitly incorporates the seasonal variations of precipitation and runoff by looking at the highest water quality violation and applying it to the entire stream flow record when calculating the TMDL.

8.0 TMDL Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairments on Mill Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent “TMDL Implementation Plan Guidance Manual”, published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

8.1 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems. The Mill Creek watershed falls within the boundaries of the Chesapeake Bay and therefore, all residents connected to a septic system must comply with a mandatory 5-year pump-out rule.

In urban areas, BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

Areas where there are dense dog populations or kennels would benefit from pet waste education programs, placement of dog waste bag stations (parks or trails), in addition to pet composting systems (depending on soil conditions) for landowners or septic systems for kennels.

An additional requirement under the Chesapeake Bay Act is the maintenance of a 100 foot wide buffer for resource protection areas (RPAs). RPAs are known as aquatic corridors which can foster natural vegetation and serve as buffers to remove pollutants, provide surface area for groundwater recharge, shoreline protection, and wildlife habitat. Education of landowners along the stream edge of Mill Creek and Kissinger Millpond would be a relatively inexpensive way of preserving these corridors and buffer restoration may also be applicable in the watershed.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

8.2. Stage 1 scenarios

The goal of the stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. A margin of safety was not used in determining the stage 1 scenarios.

As stated in Section 7 the TMDL requires a 97% reduction in non-point source loading for Mill Creek in order to attain a 0% violation of water quality standards. In order to evaluate interim reduction goals for a phased implementation plan, several reduction levels and their associated violation rates were assessed. Reduction curves for 75%, 65%, and 45% reductions, similar to the max exceedance/reduction curve of Figures 13 and 14, were plotted on the Mill Creek load-duration curve. The reduction curves are presented in Figure 17 for Mill Creek.

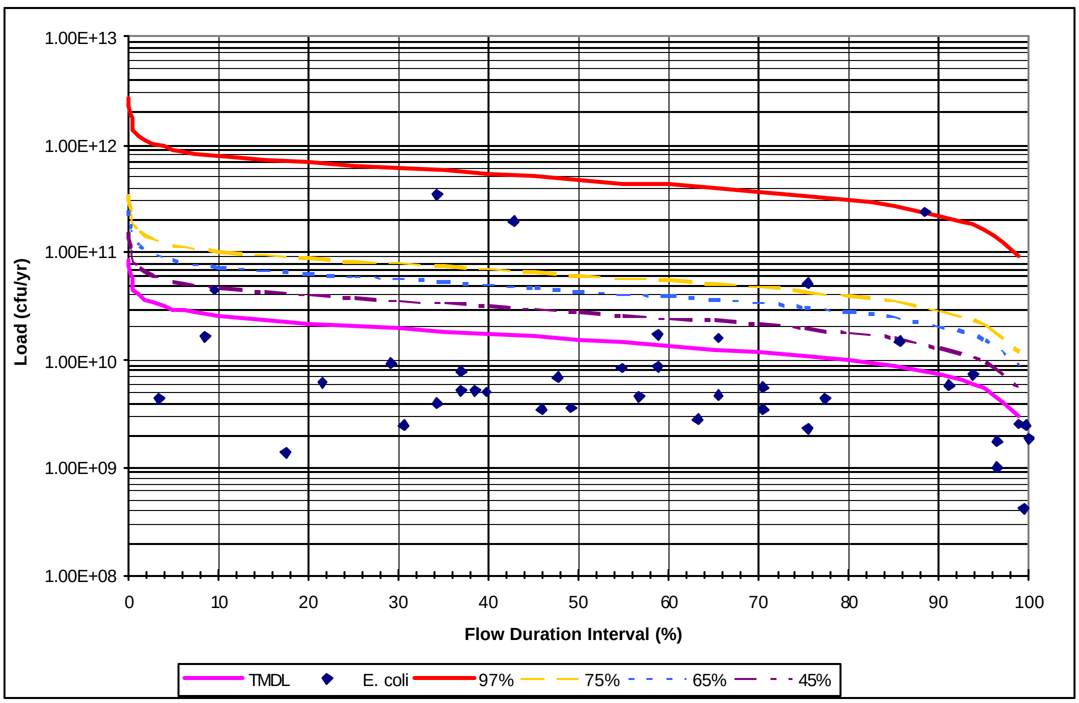

Figure 15. Daily load duration curve illustrating the TMDL and reduction curves for Mill Creek at station 1AMIA004.12 (in cfu/day).

For Mill Creek, the theoretical violation rates for the various load reductions (Figure 17) are shown below in Table 18. These were calculated by dividing the number of *E. coli* load datapoints above each respective % reduction curve by the total number of *E. coli* load datapoints (40).

Table 17. Load Reductions and WQS Violation Rates

Load Reduction	Violation Rate
97%	0%
75%	10.3%
65%	10.3%
45%	10.3%

Based on the reduction analysis presented above and a goal of approximately 10% or fewer violations of the water quality standard, a suitable Phase I reduction level for Mill Creek would be as low as 45%. Table 19 presents the Phase I load allocations for Mill Creek based on a 45% reduction of in-stream loads.

Table 18. Phase I Scenario with 45% Reduction (resulting in violation rate of 10.3%). Reductions were confined to Livestock non-point sources.

Impaired Waterbody	Fecal Type	Allocation % of Total Load	Current Load *E. coli* (cfu / day)	45% Reduction Scenario	45% ReductionTarget Load (cfu/day)
Mill Creek VAP-A33R-01-BAC	**Wildlife**	**5.46%**	**6.66E+10**	**0%**	**0.00E+00**
	Human	**2.67%**	**3.26E+10**	**0%**	**0.00E+00**
	Livestock	**90.82%**	**1.11E+12**	**40%**	**6.71E+11**
	Pets	**1.05%**	**1.28E+10**	**0%**	**0.00E+00**
	Total	**100.00%**	**1.22E+12**	**45%**	**6.71E+11**

At the 45 percent daily load reduction level, which results in a 10.3% violation rate (which is expected to have the same benefit as 65% and 75% load reductions), the total allowable daily load (6.71E+11 cfu/day) is greater than the current wildlife load (6.66E+10 cfu/day). Lower reductions in livestock *E. coli* loads than 100% may be adequate to reduce *E. coli* loads and percent violations to less than 10 percent above the water quality standard. The use of staged implementation may indicate that the TMDL reduction may be achieved before the implementation of all possible BMPs. This is not surprising given the use of conservative estimates and the implicit margin of safety.

In order to provide some insight into the nature of the Mill Creek water quality violations and to better target possible BMPs, the correlation between violations, stream flow change, and local precipitation was examined.

Results indicate that approximately 86% of the violations occurred during times of precipitation and increasing stream flow or just after a precipitation event with stable or decreasing stream flow. This suggests that those violations could be related to runoff events. The complete analysis is presented in Appendix E.

BMPs effective in correcting dry weather/low-flow violations of the bacteria water quality standard typically include: streamside fencing for cattle exclusion, straight pipe replacement, and septic system repair. Among some of the BMPs effective in reducing bacteria runoff from precipitation events include: riparian buffers zone, retention ponds/basins, range and pasture management, and animal waste management. Detailed lists of BMPs and their relative effectiveness will be presented in the eventual TMDL implementation plan for the Mill Creek watershed.

8.2.1 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. A tributary strategy has recently been developed for the Potomac River Basin to address the nutrient and sediment reductions required to restore the health of the

Chesapeake Bay. Up-to-date information on this effort and others throughout Virginia can be found at the tributary strategy web site under http://www.naturalresources.virginia.gov/Initiatives/WaterQuality/. While ongoing restoration efforts are unknown, DEQ and DCR will work with local planning districts and counties to incorporate long term objectives as well as citizen watershed groups and non-profit organizations to achieve long term water quality improvement goals.

8.3 Reasonable Assurance for Implementation

8.3.1 Follow-Up Monitoring

VADEQ will continue monitoring 1AMIA004.12 in accordance with its ambient watershed monitoring program to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards. This station will be monitored for a two-year cycle, occurring every six years. Mill Creek was last monitored during the period May 2008 through June 2009. The next ambient watershed monitoring cycle for Mill Creek will begin in 2014 for two years on a bi-monthly basis, unless required sooner to monitor TMDL implementation progress.

8.3.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

8.3.3. Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act, which is a source of funds for Virginia's Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia Environmental Endowment fund, National Fish and Wildlife Foundation, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

8.3.4 Addressing Wildlife Contributions

While it does not appear to be the case with Mill Creek, in some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream may not attain standards under all flow regimes at all times. Such streams may not be able to attain standards without some reduction in wildlife load. Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address this issue, Virginia has proposed (during its recent triennial water quality standards review) a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria will become effective pending EPA approval and can be found at http://www.deq.state.va.us/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of bacterial contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process.

Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in section 8.1 above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

9. Public Participation

The development of the Mill Creek TMDL is not possible without public participation. A set of first public meetings were held at the Northumberland Public Library in Heathsville, VA on December 16, 2009 to discuss the process for TMDL development and the source assessment input, which a total of 11 persons attended. A final set of public meetings were held at the same location on April 28, 2010 to discuss the TMDL results and the draft report, including load allocations, which 2 persons attended. Copies of presentation materials were made available for public distribution. The public meetings were public noticed in the Virginia Register, the local paper, and road signs were strategically placed throughout the watershed to gain public interest. Thirty day-public comment periods were held after each set of public meetings. XX comments were received during the final comment period.

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Appendix A

Glossary

GLOSSARY

Note: All entries in italics are taken from USEPA (1998). All non-italicized entries are taken from MapTech (2002).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge permits (under NPDES). *A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the*

Federal Clean Water Act.

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Existing use. *Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

Hydrograph. *A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology. *The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Isolate. An inbreeding biological population that is isolated from similar populations by physical or other means.

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the* *receiving waterbody (CWA section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mathematical model. *A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one or more individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.*

Mean. The sum of the values in a data set divided by the number of values in the data set.
MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Narrative criteria. *Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Non-point source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets. *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Peak runoff. *The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

Permit. *An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Phased approach. *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Privately owned treatment works. *Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period. *The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Raw sewage. *Untreated municipal sewage.*

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Restoration. *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone. *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Septic system. *An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 ml geometric mean limit).

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Surface area. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

DACS. Department of Agriculture and Consumer Services.

DCR. Department of Conservation and Recreation.

DEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also* ***Domestic wastewater****.*

Wastewater treatment. *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality. *The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality criteria. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

Appendix B

Non-point Source Fecal Coliform Contribution

Table B. Non-point Source Population Estimates and Fecal Coliform Contribution in Mill Creek

Values for Non-point sources were entered into an Excel spreadsheet to calculate the estimated total Fecal Coliform production in the watershed by source type. Superscripts in the first column refer to references below.

Mill Creek FC - Non-Point Source Load Calculations by Type	**Values selected for TMDL development**	**Population Estimates**	**Total Estimated Production**
Source Type	Fecal Coliform (cfu/animal/day)	(# source types /per watershed)	Fecal Coliform (cfu/source type/day)
Other Dairy Cow (heifer)[1]	1.16E+10	0	0.00E+00
Dairy cow[1]	2.52E+10	0	0.00E+00
Beef cow[1]	3.30E+10	50	1.65E+12
Hog[2]	1.08E+10	0	0.00E+00
Sheep[1]	2.70E+10	0	0.00E+00
Horse[1]	4.20E+08	4	1.68E+09
Chicken (Layer)[2]	1.36E+08	30	4.08E+09
Turkey[1]	9.30E+07	0	0.00E+00
Duck[1]	2.43E+09	0	0.00E+00
Goose[1]	7.99E+08	50	4.00E+10
Deer[1]	3.47E+08	75	2.60E+10
Beaver[1]	2.00E+05	2	4.00E+05
Raccoon[1]	1.13E+08	112	1.27E+10
Dog[3]	2.16E+08	96	2.07E+10
Cat[4]	1.75E+02	0	0.00E+00
Muskrat [1]	2.50E+07	770	1.93E+10
Wild Turkey [1]	9.30E+07	0	0.00E+00
Mallard[1]	2.43E+09	0	0.00E+00
Wood Duck [1]	2.43E+09	0	0.00E+00
Other Ag Animal (GOAT[5])	2.70E+10	5	1.35E+11
Other Wildlife (SWAN[6])	2.43E+09	4	9.72E+09
Human [1]	1.95E+09	27	5.27E+10
Total			1.97E+12

References below contain the as cited production values in terms of waste load and/or fecal coliform per gram. These reports may use values cited from other sources (ie. Yagow, Gelreich, etc.)

[1]Virginia Tech. Fecal Coliform TMDL for Sheep Creek, Elk Creek, Machine Creek, Little Otter River, and Lower Big Otter River in Bedford and Campbell Counties, Virginia. 12/2000.

[2]ASAE Standards, 45th edition. 1998. D348.1. DEC93. Manure production and characteristics. St. Joseph, Mich.: ASAE.

[3]MapTech. Fecal Coliform TMDL (Total Maximum Daily Load) Development for Gills Creek Impairments. Virginia. 4/2002.

[4]MapTech. E. coli Total Maximum Daily Load Development for Blackwater River & Tributaries. Virginia. 2/2010.

[5]MapTech. Fecal Coliform TMDL (Total Maximum Daily Load) Development for Middle Blackwater River. Virginia. 2/2000

[6] Maryland Department of the Environment (MDE). Total Maximum Daily Loads of Fecal Coliform for the Restricted Shellfish Harvesting Area in the Lower Choptank River Mainstem in Dorchester and Talbot Counties, Maryland. 2006.

Appendix C

Calculations

Calculations

Allowable Load Calculation from Section 6.14.

TMDL cfu/day = **1% percent flow duration** Q ft^3/s * 7.48 gal/ft^3 * 3.785 l/gal * 1000 ml/l * 235 cfu/100 ml * 60 s/min * 60 min/day * 24 hrs/day ,
Or TMDL cfu/day = **1% percent flow duration**)Q ft^3/s * 2.098176173 x 10^{12}

Where:

TMDL cfu/day = Allowable load in cfu/day
235 cfu/100 ml = Instantaneous *E. coli* standard
1% percent load duration)**Q ft^3/s** = 99% percentile highest flow in cubic feet per second
cfu = *E. coli* colony forming units.
l = liters
ml = milliliters
s = seconds
min = minutes
yr = year
gal = gallons

Required Reduction Calculation from Section 7

TMDL cfu/day = LA cfu/day + WLA cfu/day + MOS (cfu/day)

% reduction = [(CL - TMDL)/CL] * 100

Where:

TMDL = total maximum daily load (@ 1% percent load duration)
LA = load allocation
WLA = waste load allocation
MOS = margin of safety (implicit)
OL = observed load (@ 1% percent load duration)

Appendix D

Reference Stream Selection

Once several possible reference watersheds are selected, a correlation analysis is performed on the flow measurements of the reference and target gauges. Usually the reference gauge with the strongest correlation to the target gauge is selected; however, the final decision is subject to best professional judgment. In some cases a watershed with a lower correlation may be a better choice.

The reference stream correlation is performed by entering the flow measurement data from the target stream (Mill Creek) into an Excel spreadsheet along with daily mean flow data from the reference streams. The Excel "Correlation" data analysis tool is then run to determine "R" or the Pearson's correlation coefficient which can be used as an indication of the strength of the correlation. In this analysis absolute values of the Pearson's coefficient between 0-0.19 were regarded as indicating a very weak correlation, 0.2-0.39 as weak, 0.40-0.59 as moderate, 0.6-0.79 as strong and 0.8-1 as a very strong correlation.

Using the Excel graphing package, the measurement data from Mill Creek were plotted against the corresponding daily mean flow data for the Piscataway Creek gage. Excel was then used to draw a best-fit line through the data points and develop the equation for the "regression" line (Figure A). Using the equation for the regression line, daily mean flow values from Piscataway Creek could be plugged into the "x" or independent variable in the equation and the flow at the Mill Creek site, the "y" or dependent variable, could be calculated.

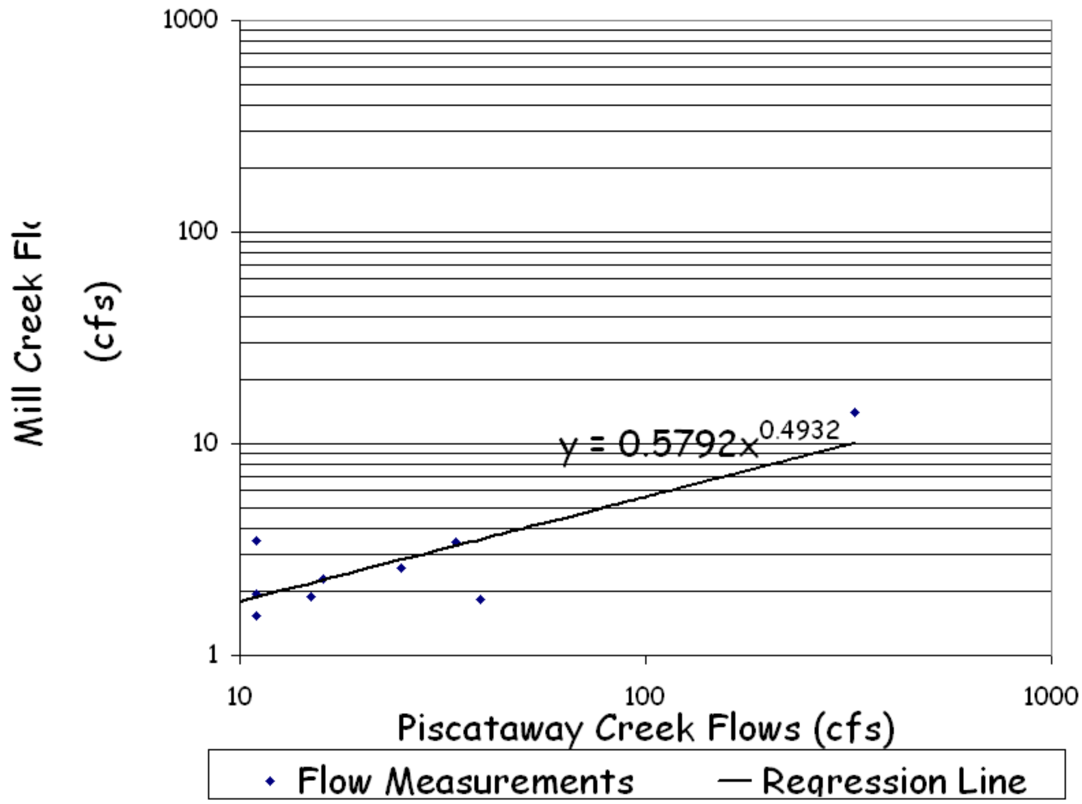

Figure D. Flow Regression for Piscataway Creek vs. Mill Creek

Appendix E

Flow Change and Precipitation Analysis

In order to better target BMPs for the Mill Creek watershed, the correlation between water quality violations, stream flow changes and precipitation was investigated. The goal was to determine which violations might be related to runoff and which might be related to direct deposition.

As stated in Section 6.1 on flow data, there was no continuous stream gage in the Mill Creek watershed, so there is little historic flow data. For this reason, the continuous gage at Piscataway Creek near Tappahannock, VA (USGS Gage 01669000) was used to develop the flow duration curve for Mill Creek. When assessing the correlation between flow change and violations, flow changes at the Piscataway Creek gage were examined. The theory is that flow changes at the Piscataway Creek gage, located approximately **16 miles southwest of the** Mill Creek site, would reflect flow changes in Mill Creek. Changes in flow might, in turn, signify runoff from precipitation events.

To assess the link between flow changes and precipitation events, precipitation records from the Warsaw, VA weather station (COOP ID 448894), located north of the Rappahannock River in Richmond County, were examined. Daily precipitation records were provided by the Southeast Regional Climate Center, http://www.sercc.com/climateinfo/historical/historical_va.html.Precipitation events on the day before and on the day of each violation were examined. Precipitation events on the day before the violation were examined to see if decreasing flows on violation days were the result of a precipitation event within the preceding 24 hours.

Results of the study are presented graphically and in tabular format below.

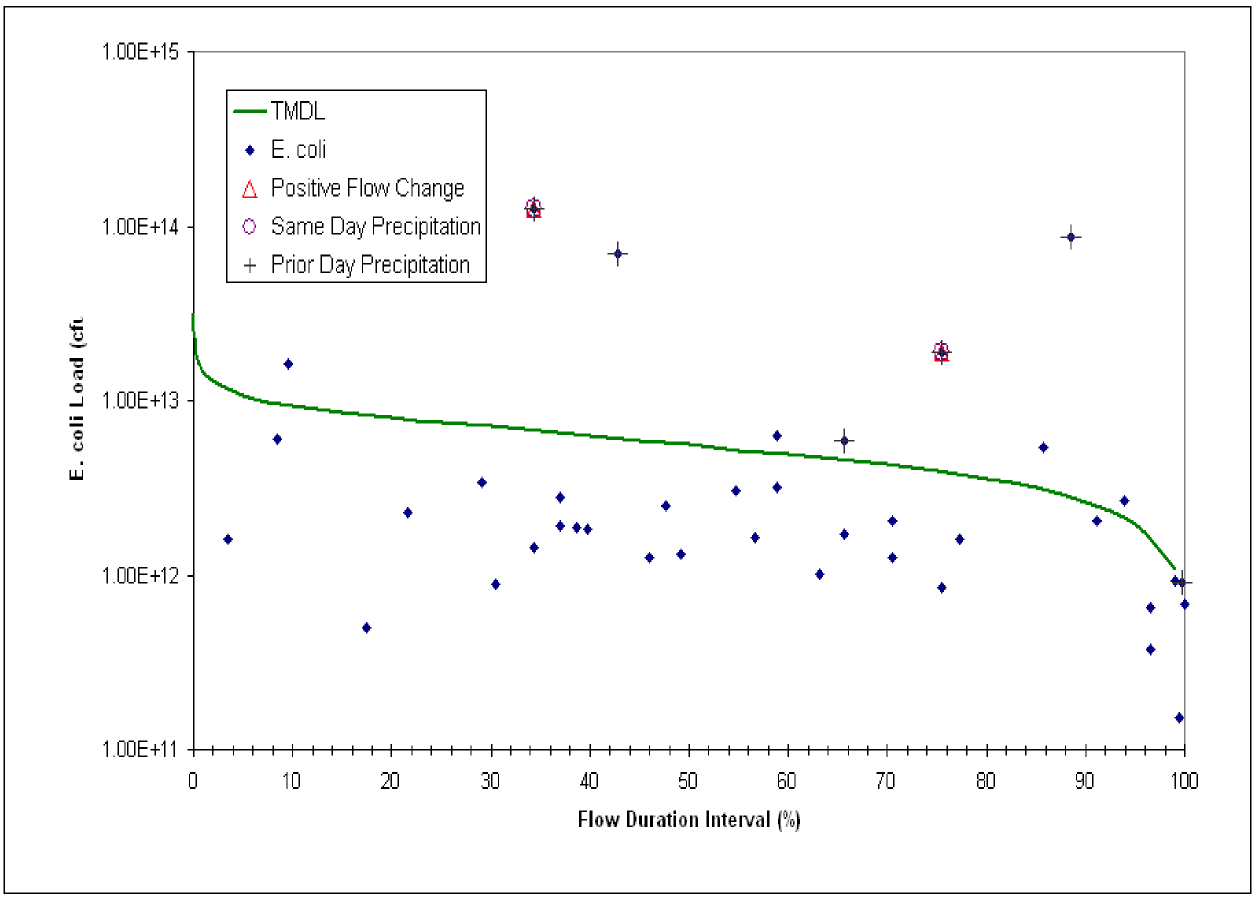

Figure E. Precipitation and Flow Annotated Violations in Mill Creek Watershed

Table E. Water Quality Standard Violations, Stream Flow Change, and Precipitation in Mill Creek

Sampling Date	Fecal Coliform Analytical Result (cfu/100 mL)	Translated E. coli Value (cfu/100 mL)	Target Stream Flow (cfs)	Duration Interval (%)	E. coli Load (cfu/yr)	Increasing Flow? (days preceeding is flow lower?)	Same Day Precipitation (in)	Prior Day Precipitation (total for previous 3 days)(in)
8/20/1996	5400.0000	2661	2.94	42.8	6.99E+13	No	0	0.39
8/13/1998	16000.0000	7221	1.35	88.5	8.74E+13	No	0	0.42
12/9/1998	9200.0000	4343	3.25	34.4	1.26E+14	Yes	0.1	0.29
8/14/2000	2100.0000	1117	1.89	75.5	1.89E+13	Yes	0.13	0.41
8/18/2008	Ecoli samples	400.0000	0.26	99.7	9.12E+11	No	0	0.39
5/13/2009		300.0000	2.20	65.6	5.90E+12	No	0	0.39
6/17/2009		400.0000	1.50	85.7	5.36E+12	No	0	
	Positive flow change with same day or prior day precipitation event							
	Negative or stable flow change with prior day precipitation event							

The results of the study suggest that as many as 6 of the 7 violations (86%) could be related to runoff events (prior day precipitation with negative stable flow change and positive flow change with same and or prior day precipitation.

Additional information regarding the nature of the violation can be gleaned from looking at the flow conditions under which the violations occur. Four of the violations including the violation requiring the highest load reduction occurred during low flow conditions.

Appendix F

Public Comments